ANL-7541

ANL-7541

E. M. Dean

Argonne National Laboratory

A DOCUMENTATION OF
CRITICALITY DATA FOR EBR-II WITH
A STAINLESS STEEL RADIAL REFLECTOR

by

J. K. Long and W. R. Wallin

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

A DOCUMENTATION OF
CRITICALITY DATA FOR EBR-II WITH
A STAINLESS STEEL RADIAL REFLECTOR

by

J. K. Long and W. R. Wallin

EBR-II Project

April 1970

TABLE OF CONTENTS

4

LIST OF FIGURES

LIST OF FIGURES

6

LIST OF TABLES

A DOCUMENTATION OF
CRITICALITY DATA FOR EBR-II WITH
A STAINLESS STEEL RADIAL REFLECTOR

by

J. K. Long and W. R. Wallin

ABSTRACT

During 1967 and the first half of 1968, the EBR-II reactor was operated with stainless steel subassemblies replacing its original depleted-uranium subassemblies in the inner two rows of the radial reflector. This report documents all data on the power coefficient of reactivity from the last run before the stainless steel substitution (run 24) up through and including the first runs for which depleted uranium was restored in this region (runs 29C and 29D). Core-loading diagrams for all core configurations during this period are included. A tabulation is also included of the results of studies of the power coefficient of reactivity at reduced flow. Reduced-flow studies were pursued extensively during the period to aid in distinguishing the fuel component from other components of the power coefficient of reactivity. This report also contains a tabulation of the results of observations of slow periodic variations in power that occurred when the reactor was allowed to drift. These slow variations only appeared when the stainless steel radial reflector was installed, and they disappeared when the depleted-uranium reflector was restored.

I. INTRODUCTION

The basic configuration of the Experimental Breeder Reactor II (EBR-II) as originally assembled is described in the safety analysis reports[1,2] and in various other reported studies of early operation of the reactor.[3,4] EBR-II is a sodium-cooled, metal-fueled fast reactor whose cores have varied in size from roughly 70 to 90 liters. It is located at the National Reactor Testing Station in eastern Idaho and is operated for the Atomic Energy Commission by Argonne National Laboratory. During the period covered in this report, it was being used as a fast-neutron irradiation facility at thermal-power levels up to a nominal 45 MW.

Early in 1967, the inner two rows of depleted-uranium blanket sub-assemblies (rows 7 and 8 of the hexagonal EBR-II geometry) were replaced with stainless steel, thereby increasing the reactivity and the availability of the reactor for irradiation experiments. The temperature changes and the associated changes in the power coefficient of reactivity that accom-panied these substitutions were significant, and their study has increased the understanding of the behavior of the reactor.

A complete documentation of the power coefficient of reactivity during this period has been prepared as the principal subject of this report to provide a basis for future analysis. Some definitions of terms and de-scriptions of experimental methods are given first, followed by an abbre-viated chronology of the pertinent reactor events during the period. These serve as explanatory background for the tabulations of reactivity data and diagrams of reactor loading that follow.

II. DEFINITIONS AND EXPERIMENTAL METHODS

A. Reactor Run

EBR-II operations are divided into numbered runs, a run being completed when the reactor is shut down for reloading of spent fuel. Some runs are divided further into subruns (A, B, C, etc.) designating changes in experimental loadings or reactivity adjustments without replacement of sub-stantial amounts of spent fuel. For runs 1-24, the depleted-uranium blanket was installed next to the core, in rows 8 and 7 and part of row 6. In run 25, the depleted-uranium blanket subassemblies in rows 7 and 8 and the noncore portion of row 6 were replaced with stainless steel subassemblies, a con-figuration that was maintained, except for experimental-irradiation substitu-tions, through run 29A.

B. Reactivity

Reactivity is measured by the position of a calibrated control rod. The rod is used for control over a range in which its worth is essentially linear with respect to its length. It is calibrated for each new reactor con-figuration by making period measurements in the linear portion of the rod range. Although the total worth of any control rod varies with the reactor loading, numerous measurements have failed to detect any significant change in shape of the curves of rod worth versus position. However, there is a detectable difference between the shapes of the curves for odd- and even-numbered rods, which are located at the corners and flats, respectively, of the row-5 hexagonal geometry. Consequently, over the course of EBR-II operations, criticality has been determined by reference to the shape of the reactivity curves from the first EBR-II runs, but scaled according to the current period calibration.

Reactivity values have been corrected by 1 Ih for each degree Fahrenheit that the temperature of the bulk sodium differs from 700°F, a figure derived from measurements of isothermal temperature coefficients. Burn-up during each run has been corrected consistently at the rate of 0.15 Ih/MWd. This is appropriate for startup after an extended shutdown, when ^{239}Np has decayed out of the fuel.

The inhour has been adopted as the unit of reactivity appropriate for this report because of its close correspondence with period measurements. With a depleted-uranium blanket, a 1% change in reactivity ($\Delta k/k$) is calculated to be worth 430 Ih. With the stainless steel radial reflector, a 1% change in reactivity is calculated to be worth 425 Ih. (The latter figure supersedes the value of 404 Ih used in some earlier reports.)

C. Core Size

Core size is defined arbitrarily as the number of subassemblies in rows 1-5, plus the number of full or partial driver subassemblies and of fueled experimental subassemblies in row 6.

D. Power-reactivity Decrement

The term power-reactivity decrement (PRD) is used throughout this report to mean the integral with respect to power of the power coefficient of reactivity; thus,

$$ \text{PRD} = \int_{0}^{Q'} \frac{d\rho}{dQ} \ dQ = \rho(Q'), $$

where ρ and Q signify reactivity and reactor thermal power, respectively. Since the reactor normally loses reactivity as it is brought to power, the PRD is an algebraically negative quantity. For convenience, however, the negative of this quantity is tabulated in this report. Hence, most of the values appear as positive.

The power range during the period of study was limited to 45 MW, although the reactor operating range was subsequently extended to 50 MW, and more recently to 62.5 MW. (Reactor thermal power was raised to 50 MW in August 1968. A demonstration run at 62.5 MW was made in September 1969.)

E. Reactor Power

Reactor power is measured basically by heat output--this in turn being derived from the flowrate and temperature rise of the primary sodium--and is cross-checked by heat balances of the secondary sodium and steam

systems. Discrepancies[5] in these cross-checks have been reconciled by careful calibration of instruments to within 1%.[6] In day-to-day operation, uncertainties in calibrating and recording the temperature and flow instruments probably lead to unrecorded variations in operating power of at least an additional 1%.

Channel 7 of the nuclear instrumentation has been adopted as a secondary standard for reactor power. The channel-7 detector is a gamma-compensated ion chamber, Type GE-NA09. This must be recalibrated against a heat balance for each run in which it is used, because the flux reaching the instrument is dependent on the reactor loading. When channel-7 data were not available, power levels were calculated from the rise in temperature, ΔT, of the primary sodium, as indicated at the reactor control console, by the formula

$$Q = 0.333(\Delta T + 3),$$

where Q is in MW, and T is in degrees Fahrenheit. The three-degree addition to ΔT is required because of the initial placement and calibration of the thermocouples.

Temperatures are subject to a relative uncertainty of $\pm 1.5°F$ over a period of a few days. For those runs in which channel-7 data are available, relative power levels are probably reliable to within $\pm 0.5\%$. Flowmeter sensing and indicating equipment has a reproducibility uncertainty of about $\pm 1\%$.

III. SPECIAL CHARACTERISTICS OF THE POWER-REACTIVITY DECREMENT

A. Hysteresis

The ascending and descending PRD curves have never coincided since the earliest EBR-II runs.[5] The current data show that the curves still do not coincide; they are, in fact, further apart. A qualitative judgment of the extent of hysteresis can be formed quickly by comparing the ascending and descending PRD curves in the neighborhood of 30 MW. The descending PRD's are invariably larger (in absolute magnitude) than the ascending PRD's in this region. The difference has varied from 3 to 6 Ih.

Typically, with the stainless steel reflector, a reduction in power from 45 to 30 MW was accompanied by a gain in reactivity of about 10 Ih, where 13 to 16 Ih would have been expected if the ascending curve had been followed. After continued descent to zero power, the critical position was usually 2 to 4 Ih above or below the start of the ascending curve, even after correction for decay heat and neptunium effects.

Since the hysteresis effects may be dependent, in an unknown fashion, on the time scale on which they are measured, efforts have been made to adopt more or less standard time sequences for PRD measurements. For example, ascending curves seem to be most reproducible if they all consist of 6 to 10 measured points with 1 to 2 hr of residence (for leveling and equilibrating the reactor) at each point.

The pattern of PRD data taken in runs 29A and 29C was designed to investigate the observed hysteresis effects. If the curve for steady-state PRD has a different slope under different conditions or at different times, the detailed interpretation of the rod-drop experiments might have to take into consideration the previous power history of the reactor. Little direct information was available on this subject. Experiments were designed to study the following two possible explanations.

First, the hysteresis observations may be interpreted in terms of phase changes in the fuel, which are known to affect the fuel density and the linear-expansion coefficient. The transformation from gamma to alpha phase has a substantial time dependence. Once the gamma phase is established in the metallurgical structure, its removal by annealing may be delayed depending on both time and temperature. A small, but significant, fraction of the fuel may be above the gamma-phase transition temperature (1150°F) at 45 MW; however, at 41.5 MW, practically none of the fuel is expected to be above this temperature. Therefore, if the delays in gamma-phase annealing are a significant source of hysteresis, then hysteresis should be somewhat different, depending on whether the reactor is cycled between zero power and 41.5 MW or between zero power and 45 MW. (When this experiment was planned, only a rough estimate of the worth of fuel material in the gamma phase was available. Subsequently, more-exact calculations have shown that the effect of gamma phase on power coefficient of reactivity would be only 2-5%, and hence not observable, between 41.5 and 45 MW. The effect is probably observable, however, between 41.5 and 62.5 MW.)

Second, if the hysteresis is governed by a somehow delayed adjustment of subassembly clearances, the initial power cycles after a major reloading change, when clearances are distributed in the most-random fashion, might reveal significant hysteresis information.

The program to investigate hysteresis consisted in cycling the reactor once each between zero power and 25 MW, zero power and 41.5 MW, and zero power and 45 MW.

The results are given in the PRD column of Table III, in the part covering June 27 to June 29, 1968. The slopes of the PRD curves for increasing and decreasing power during the first cycle--zero power to 25 MW and return--are nearly the same in the neighborhood of 25 MW. The long-term feedback in this power range, therefore, should not be influenced by

whether the power is increasing or decreasing. The cycles to 41.5 and 45 MW both show some hysteresis effects. The accuracy of the data probably does not justify the interpretation that there are different hysteresis effects in the two cases. Since the gamma phase is not present at 41.5 MW and has not increased significantly at 45 MW, it would appear not to be responsible for the hysteresis. Finally, the hysteresis effects do not seem significantly different from those observed in the later stages of a run, after clearances between subassemblies are supposedly more ordered. (See, for example, in Table III, the end of run 25 on 8/17/67, in which there is about a 6-Ih separation between the ascending and descending curves.) Consequently, no direct connection can be said to have been found between either clearances and hysteresis or between possible fuel-phase kinetics and hysteresis.

The PRD cycles also failed to disclose any improved way of treating the rod-drop data in the midpower range, because no significant difference was observed in the slopes of the PRD curves for increasing and decreasing power around 25 MW.

B. Effects of Thermal Expansion of Control-rod Handles[7]

The control rods are supported above the core near the top of the rotating shield plug, and the core is supported by the bottom grid plates. These grid plates are supported, along with the reactor vessel, by the bottom of the reactor tank. The upper extension shafts that support the control rods are immersed in sodium that has passed through the core. The length of these shafts changes because of variations in sodium temperature, which depends on reactor power. The variations in lengths of the shafts resulting from thermal expansion change the position of each control rod relative to the core.

Since the worth of the control rod in its banked position is not linear with respect to the rod length inserted into the core, the amount of reactivity contributed by the thermal expansion is different, depending on the length inserted. Consequently, this expansion effect was calculated and taken into consideration when power-reactivity decrements were compared at different conditions of control-rod banking. All PRD values were corrected to the condition where the bank of all the control rods is set at 11-in. insertion, a common situation at the start of a run.

At 50 MW, the difference in reactivity due to a rearrangement of the rod bank from the 11.0-in. insertion to a pattern where one rod is at 0.0 in. and the rest at 14.0 in. has been calculated to be 11.5 Ih. The measured difference was 14.2 Ih, which is regarded as reasonably good agreement. Other measurements, both at full and reduced rates of coolant flow, have verified roughly that the rod-bank expansion effect is proportional to the rise in temperature of the sodium as has been assumed.[8]

C. Effects of Reduced Flow of Coolant

Any difference in PRD measured at two operating conditions in which the rise in sodium temperature is the same is due primarily to the difference in the temperature of the fuel elements. The effects of subassembly bowing and rod-bank expansion are dependent principally on the sodium temperature, which is the same in each case. In an effort to understand the contribution of the fuel element to the PRD and to ascertain whether this contribution varies substantially, several reduced-flow measurements have been made during and since run 25.

Comparisons of the PRD change between the constant-ΔT reactor operating conditions of 41.7 MW with full flow and 22.5 MW with 54% flow indicate the effect of thermal expansion of fuel on reactivity. Since minor deviations from this standard pair of operating conditions are bound to be encountered while measurements are being made, a method of calculating the partial derivatives is used for making first-order corrections in PRD to account for deviations in power and flow.

Much of the data obtained from reduced-flow experiments cannot be interpreted by the simple two-point constant-ΔT analysis. Therefore, a general analysis interpreting the PRD over the whole range of reduced power and flow was made to allow full use of the experimental data. This analysis was based on the assumption that the total PRD at any flowrate up to full flow is the sum of the PRD components that are linear with power (expansion of fuel, coolant, structure, control-rod handles, etc.) and those (such as bowing) that, although not linear with power, can be assumed to be single-valued functions of the temperature rise of the sodium. (Reactor power is proportional to the temperature rise of the sodium at any given flowrate.)

The total PRD at full flow is known as a function of the temperature rise of the sodium from the experimental data routinely obtained at startup. The nonlinear components of the PRD at full flow can be obtained by subtracting the known linear components from the total PRD. Then, nonlinear components at reduced flow may be calculated from the full-flow condition that yields the same sodium temperature rise, and added to the linear component computed for the reduced-flow condition to obtain the PRD.

The linear components of the reactivity effects of expansion were calculated by two-dimensional reactor diffusion theory. Although this procedure yielded fairly good agreement between experimental and calculated PRD's at reduced flow, consistent small differences led to the suspicion that the linear portion that had been used in this procedure was not known as well as desired. Reconsideration showed that there were uncertainties in the expansion coefficient of the fuel due to its transition to the gamma phase, to known variations of conductivity with burnup, and to possible

unknown burnup effects. A least-squares procedure therefore was devised to determine exactly what magnitude of linear component should be subtracted from the full-flow PRD curve to yield a combination of linear and nonlinear components that best fit all the reduced-flow PRD data for a given run.

With the assumption that all portions of the linear component except the fuel-expansion coefficient were known, a value of an effective fuel-expansion coefficient, α, was then determined consistent with the reduced-flow data for each run. A description of the procedure in greater detail has been published.[9]

Each set of reduced-flow data therefore results in two parameters which characterize the fuel. The first is the reactivity difference for a standard pair of constant-ΔT conditions; and second is an effective fuel-expansion coefficient, α, based on all available reduced-flow data for a given reactor condition. These parameters are given in Table I. For reference, the average value of α for clean fissium fuel is about $23 \times 10^{-6} \, °C^{-1}$. The tabulated effective α values include whatever contributions may be present from fuels other than fissium in the core, as well as any effects due to fuel burnup.

TABLE I. Results of Reduced-flow Experiments and Calculations

Date	Run	MWd[a]	Δk[b] at Constant ΔT, Ih	Effective α, $10^{-6} \, °C^{-1}$
5/16/67	25	200	7.1	23.6
9/27/67	26A	200	8.8	23.9
10/19/67	26B	200	11.3	c
11/6/67	26C	1000	11.6	37.6
11/29/67	26C	1300	9.8	c
12/10/67	26C	1700	14.8	47.2
2/8/68	27A	100	7.7	c
3/8/68	27C	500	6.9	23.1
5/2/68	27H	1200	10.8	27.0
5/10/68	28A	0	9.5	c
5/20/68	28B	300	9.0	22.8
6/3/68	28C	600	10.4	c
7/2/68	29A	100	8.22	23.8
7/10/68	29B	200	9.05	c
7/19/68	29C	300	6.20	14.1

[a]MWd: Megawatt days the reactor had sustained since the last major loading change at the start of the run whose number is indicated in the second column.
[b]Reactivity change observed between the standard constant-ΔT conditions of 41.7 MW with full flow and 22.5 MW with 54% flow.
[c]Insufficient data for calculation.

D. Slow Periodic Variations in Reactor Power

After the introduction of the stainless steel reflector, constant reactor power level was more difficult to achieve than in earlier runs (runs 1-24). No matter how carefully the position of the control rods and flow of secondary coolant were balanced at a given power, the reactor power would not hold constant without further adjustments for more than about 5 min. Then if no adjustments were made, the power level would drift up or down by as much as a megawatt, pass through a maximum (or minimum) after about 5 more min, and then tend toward a slow oscillation with perhaps 2-MW peak-to-peak amplitude and a period of the order of 20 min. Although such behavior had not been reported in runs 1-24 when the depleted-uranium blanket was installed, it could have been present and not observed.

More attention was paid to the power coefficient of reactivity during and after run 25. Observations of this nature therefore may have been taken in considerably more detail with the stainless steel reflector in place (runs 25-29A) than they had been previously. Consequently, this oscillatory behavior was studied carefully immediately before and after the restoration of the depleted-uranium blanket (runs 29A and 29C). The tendency for slow oscillations, which was invariably present and conspicuously observable in run 29A (with the stainless steel radial reflector), had disappeared entirely in run 29C (with the depleted-uranium radial reflector).

Table II shows the approximate amplitudes and periods of spontaneous oscillations observed during runs 25-29C. A detailed analysis of the oscillatory behavior is being prepared for publication.[10]

TABLE II. Amplitude and Period of Spontaneous Oscillations, Runs 25-29C

Run	Power Level, MW	Flow Fraction[a]	Peak-to-peak Amplitude, MW	Period, min	Remarks
25	15.0	1.0	1.2	33-37	
25	17.5	1.0	0.28	26-28	
25	20.0	1.0	0.68	27-29	
25	22.5	1.0	0.9	26	
25	25.0	1.0	1.8	22	
25	27.5	1.0	1.4	22	
25	30.0	1.0	2.0	24	
26	45.0	1.0	1.2	17	12.75-in. rod bank
26	45.0	1.0	1.4	17	14.0-in. rod bank
28	15.0	1.0	0.9	27	
28	25.0	1.0	2.0	23	
28	22.5	0.58	1.3	20	
28	43.0	1.0	1.4	16	
29A	41.5	1.0	2.0	17	
29A	22.5	0.58	1.0	17	
29A	23.0	1.0	4.0	23	
29C	41.5	1.0	-	-	No oscillations observed greater
29C	22.5	0.58	-	-	than 0.05 MW with periods be-
29C	23.0	1.0	-	-	tween 0.1 and 100 min

[a] Full flow is 9,000 gpm.

IV. OPERATING CHRONOLOGY

It is not the function of this report to interpret the reactor data. Nevertheless, a limited amount of reactor operating history, together with a few interpretive comments, is necessary to justify and explain the action taken during the period for which this report documents the PRD data. The abbreviated history given here therefore serves as a key to the PRD values in Table III and to the core-loading diagrams in the appendix. (A more-detailed history of reactor operations during this period can be found in the Quarterly Reports of EBR-II Operations. These reports have been distributed to reactor users and are available to other interested parties on request to the EBR-II Project.)

In January 1967, the oscillator failed during run 24, necessitating its removal at the end of the run. Several other occurrences, including an investigation of traces of copper in the coolant, delayed the start of run 25D until March. (Runs 25A, B, and C were foil irradiations at low power.) A tendency toward swelling was observed in the depleted-uranium elements in row 7, necessitating their replacement. Stainless steel subassemblies then were substituted for depleted uranium in rows 7 and 8.

When operations were resumed in run 25D, the PRD was considerably less than in previous runs. The shape of the curve of PRD versus power indicated that a positive component of the power coefficient of reactivity was making an observable contribution. The reduction in PRD was tentatively attributed in part to these positive components and in part to an increase in core size, which necessarily accompanied the larger experimental complement. Analysis showed that the positive component of the power coefficient was in all probability a result of reverse bowing of subassemblies in row 8, which resulted from the flow of heat from row 9 to the overcooled stainless steel subassemblies in row 8.

Reduced-flow and rod-drop experiments were performed. After the major features of the behavior of the power coefficient were apparently understood, operations were continued normally until a release of fission gas on May 24, 1967. Several low-power runs then were made to identify the leaking subassembly, which proved to be an experimental oxide subassembly, X011. This experiment was removed.

When normal operations were resumed, a series of further small reductions in PRD was observed. An attempt was made to explain these reductions in terms of progressive reductions in blanket clearances by jiggling the blanket elements. The experiment proved inconclusive; although a 2- to 3-Ih increase in PRD was noted, particularly in the midpower range, this apparent increase could have been the result of experimental uncertainties. It then was concluded that most of the decline of PRD during run 25

(and similar declines in previous runs) could be explained by the effect of expansion of the bank of control-rod handles. Run 25 was completed in August 1967. (Minor variations among subruns of run 25 are not included in this report; run-25 data are from run 25C.[11] Subassembly X011 was in position 2F1 during the early part of this run.)

All subsequent discussion of PRD in this report refers to the net value after the correction for expansion of the rod handles. The correction has been applied in all the values shown in Table III.

Run 26A was started with a minimum of changes from run 25. Only the spent driver subassemblies were replaced with fresh subassemblies, and the experimental complement remained the same. Initial measurements of the PRD verified the effect of expansion of the control-rod handles. After a short experimental program, including measurements of PRD at full and reduced flow, run 26A was terminated. A new oscillator rod and a new drive mechansim were loaded into control-rod position No. 8 for run 26B. Three additional subassemblies for experimental irradiation also were loaded at that time. Measurement of PRD at reduced flow, rod-drop measurements, and oscillator experiments were conducted, both at the beginning and toward the end of the 1029 MWd of run 26B. Four additional experimental subassemblies containing oxide fuel were introduced in run 26C, which continued for an additional 620 MWd. Rod-drop, oscillator, and reduced-flow measurements were made during run 26C also.

During run 26, a progressive reduction in the magnitude of the net negative power coefficient of reactivity was observed in the midpower range (15-25 MW). This reduction finally resulted in a slightly positive net power coefficient of reactivity, which was observed over a limited power range (20-25 MW) on December 11, 1967. The average coefficient from 0 to 25 MW was still negative and was close to -0.5 Ih/MW. Several observations indicating release of fission-product gas had been made before that date. These observations, together with the tendency toward continuing reduction of the magnitude of the negative power coefficient of reactivity, were deemed sufficient reasons to terminate the run shortly before it had reached its scheduled conclusion.

The reloading for run 27 involved replacement of spent driver subassemblies and installation of two metal-fueled experimental subassemblies. During this reloading, a control-rod thimble removed from reactor position 5C3 was found to have been bent at its upper edge.[12] This bent edge could have forced several of the core subassemblies slightly apart, thereby causing a rather unpredictable, though small, effect on the previous measurements of power coefficient cited above.

Run 27 was marked by evidence of a leaking subassembly. Operations were interrupted on several occasions to remove suspect experimental

subassemblies. Near the end of the run, the leaker was identified as a uranium-15 wt % Pu-10 wt % Zr metal-alloy fuel experiment (subassembly X028). The loading diagrams for runs 27A-27I show how the core decreased in size throughout run 27 as experiments were removed and, in general, replaced with driver subassemblies. On the basis of data accumulated over the past few years, it might have been expected that the PRD would increase as core size decreased during run 27. Certainly the reverse effect seemed to be occurring as the core size was built up by adding experiments in runs 1-24. No clear trend in PRD was discernible, however, as the experiments were removed and core size decreased by eight subassemblies between runs 27A and 27H. The earlier experience might have suggested an increase of about 15 Ih due to such a change.

Run 28A was a short operation (150 MWd) to verify the removal of the leaker. Consequently, only the necessary spent driver subassemblies were replaced.

In run 28B, about half the experiments (those in rows 6 and 7) were restored, and the reactor was run for about 300 MWd. Run 28C saw the restoration of the experiments in rows 4 and 5 and about 550 MWd of operation. Negative PRD's throughout run 28 ran about 6 or 7 Ih greater in magnitude than those of the previous runs with the stainless steel reflector. Again, no clear trend in change of PRD was apparent as the experiments were introduced. (This time, the net change in core size was limited to two subassemblies.) Because of mechanical problems, the oscillator was removed at the end of the run.

Spent driver subassemblies were replaced for the start of run 29A, and fueled experiments were removed from rows 7 and 8. Run 29A provided reference PRD and reduced-flow experimental data for the ensuing substitution of depleted-uranium subassemblies for stainless steel subassemblies in rows 7 and 8. Hysteresis experiments were performed as described in Section III.A.

For run 29B, 34 of the 36 stainless steel subassemblies in row 7 were replaced with subassemblies containing depleted uranium. The reactivity loss for this change was measured to be 354 Ih. Measurements showed an increase in the negative PRD of about 5-6 Ih as a result of this change.

For run 29C, the two remaining stainless steel subassemblies in row 7 and all 42 stainless steel subassemblies in row 8 were changed to depleted uranium. This change resulted in an additional 222 Ih, making a total of 576 Ih for the entire change. When the stainless steel reflector subassemblies had first been inserted in rows 7 and 8 at the beginning of run 25, their worth relative to the depleted-uranium subassemblies was

449 Ih. This earlier change differed from the run-29C change in two respects. First, plutonium worth an estimated 130-160 Ih had been accumulated in the depleted-uranium blanket subassemblies in rows 7 and 8 up to the end of run 24, whereas clean depleted uranium was substituted in run 29C. Second, four subassemblies in 6N1 positions that had been replaced after run 24 were not restored in run 29C because by that time their locations were occupied by experimental subassemblies.

Substitution of the depleted uranium for stainless steel in the four 6N1 positions would have increased the worth of the run-29 change by an estimated 30-40 Ih, thereby bringing the total worth of the change to 606-616 Ih. Correction for the plutonium in the run-25 change would increase the worth of that change to 579-609 Ih. Thus the worths of the two changes are in reasonably good agreement. To complete the configuration of run 29C, two additional driver subassemblies were loaded into the corners of the sixth row, thereby extending the core size to 91 subassemblies.

The three PRD cycles between zero power and 25 MW, zero power and 41.5 MW, and zero power and 45 MW then were repeated, revealing an interesting pattern. Not only did the point of inflection almost completely disappear from the PRD curve, consistent with a disappearance of the evidence for positive bowing effects, but the magnitude of the PRD to 45 MW was increased from 51.6 to 84.0 Ih. Hysteresis effects with the depleted-uranium blanket still were present in run 29C, the separation of the ascending and descending PRD curves being 4-5 Ih compared with 5-6 Ih with the stainless steel reflector. Again, little hysteresis was observed when the power was raised only to 25 MW, but both the 41.5- and 45-MW cycles showed a noticeable and similar hysteresis effect.

The fueled experiments were reinserted in rows 7 and 8 for run 29D.

The PRD measured in run 29C and in the following runs is consistent with the calculated linear effects of expansion of core and blanket materials, thus indicating very little, if any, contribution of bowing effects such as those inferred from data for runs 25-29A. The calculated expansion coefficient, 1.82 Ih/MW,[13,14] would account for 82 Ih of the PRD at 45 MW; the measured values at 45 MW in runs 29C and 29D ranged from 83 to 91 Ih.[11] (The coefficients for the reactor with the stainless steel radial reflector should be increased by the factor 425/404 over the values given in Ref. 12, because of recalculation of the worth of the inhour in terms of $\Delta k/k$.)

The PRD for run 29C (84.0 Ih) was considerably larger than that for run 24 (66.5 Ih). Attempts to explain this difference by the difference in core size have not led to any theory consistent with all the observed variations in size. Further attempts to explain it have called attention to the switch from recycled fuel to fresh fuel produced by the cold line. Some of

this switch was made between runs 24 and 29. There is no dilatometer evidence to support this explanation, however, and a clean corroborating experiment would be desirable.

V. VALUES OF POWER-REACTIVITY DECREMENTS FOR RUNS 24-29C

The table of power-reactivity decrements (Table III) uses the following headings, abbreviations, and units.

The first line of each section contains the date on which the PRD measurements were started; the run number, the last two digits of which represent the alphabetical suffix (e.g., 2602 = 26B); and the burnup at the start of the measurement, in megawatt days, counted from the start of the run. Then follow the numbers of control rods used to adjust criticality and the calibration factors required to scale the original worth curves to their current value.

The first column in Table III shows the time at which the reactor power was considered level (24-hr clock). If the tabulation is only of a descending PRD, the times are given in reverse order so that the lowest power appears first. The second column gives power levels in megawatts, as derived either from channel-7 data (if available) or the rise in sodium temperature. The third and fourth columns give rod position in inches (measured from the lowest, or out, position). If only one rod was used over the PRD range, the second of these columns is all zeroes. The next three columns give the corrections, in inhours, for bulk sodium temperature, burnup from the beginning of the measurement (or to the end of the measurement for descending PRD's), and the inhours required to correct to a standard rod-bank configuration of 11.0 in., respectively. Then follows the excess reactivity available in the one or two controlling rods, including the listed corrections (that is, the reactivity which would be added to the reactor if these rods, but not the banked rods, were driven to their fully raised position). The final column contains the PRD referenced to zero power.

TABLE III. Power-reactivity Decrements for Runs 24-29C

12/ 10/ 66   RUN NO. 2400   7 MWD
ROD NO. 5   CAL. 1.110
ROD NO. 11   CAL. 1.010

TIME	MW	R 5	R 11	TEMP	BU	RBNK	EXCESS	PRD
1645	.5	4.06	3.63	0.00	0.00	-.03	207.60	1.0
1715	10.7	4.06	4.96	-1.00	.02	-.74	190.45	18.1
1730	20.5	5.29	4.96	1.00	.05	-1.41	175.53	33.0
1745	25.4	5.29	5.32	0.00	.07	-1.74	169.74	38.8
1800	30.3	5.76	5.32	0.00	.10	-2.08	162.89	45.7
1900	37.6	5.97	5.86	0.00	.29	-2.58	152.82	55.7
1920	44.9	5.97	6.68	0.00	.37	-3.09	142.21	66.3

TABLE III (Contd.)

12/ 23/ 66   RUN NO. 2400   412 MWD
ROD NO. 5 CAL. 1.110
ROD NO. 11 CAL. 1.010

TIME	MW	R 5	R 11	TEMP	BU	RBNK	EXCESS	PRD
1340	.5	6.16	6.20	.50	0.00	-.03	148.67	1.0
1400	10.7	6.20	7.58	0.00	.01	-.74	130.39	19.2
1450	20.5	6.20	8.63	0.00	.10	-1.41	116.49	33.1
1535	25.4	6.20	9.05	0.00	.25	-1.74	111.22	38.4
1635	30.3	6.56	8.93	-.50	.41	-2.08	107.08	42.5
1710	37.6	7.45	8.93	0.00	.53	-2.58	95.75	53.9
1850	44.9	8.45	8.93	0.00	.89	-3.09	81.60	68.0

12/ 29/ 66   RUN NO. 2400   499 MWD
ROD NO. 5 CAL. 1.120

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD·
1343	.5	6.50	0.00	0.00	0.00	-.11	73.77	1.0
1418	10.7	7.80	0.00	0.00	.01	-2.36	54.20	20.5
1445	20.5	8.55	0.00	0.00	.04	-4.51	41.53	33.2
1505	25.4	8.94	0.00	0.00	.07	-5.58	35.20	39.5
1525	30.3	9.43	0.00	0.00	.11	-6.66	27.86	46.9
1600	30.3	9.54	0.00	0.00	.21	-6.66	26.61	48.1
1720	44.9	11.06	0.00	0.00	.46	-9.89	7.74	67.0
1800	30.3	9.44	0.00	0.00	.60	-6.66	28.23	46.5
2125	44.9	11.09	0.00	0.00	1.28	-9.89	8.29	66.4

4/ 26/ 67   RUN NO. 25   24 MWD
ROD NO. 11 CAL. 1.010
ROD NO. 4 CAL. .930

TIME	MW	R 11	R 4	TEMP	BU	RBNK	EXCESS	PRD
1145	.9	8.18	7.85	1.00	0.00	.02	103.39	2.2
1300	.5	8.01	7.85	0.00	0.00	.01	104.54	1.0
1405	1.0	8.24	7.85	0.00	.01	.02	101.64	3.9
1520	30.3	10.42	7.85	0.00	.12	.80	78.06	27.5
1600	30.3	10.42	7.85	0.00	.20	.80	78.14	27.4
1722	32.7	10.58	7.85	-1.00	.47	.87	76.04	29.5
1825	35.1	10.85	7.85	1.00	.69	.93	76.02	29.5
2038	30.3	10.70	7.85	-.50	1.09	.80	76.05	29.5
2400	29.3	10.85	7.85	0.00	1.44	.77	75.61	29.9
5	30.3	10.68	7.85	0.00	1.46	.80	77.09	28.5
800	30.3	10.68	7.85	0.00	2.94	.80	78.57	27.0
847	35.1	11.00	7.85	0.00	3.15	.93	76.26	29.3
1108	37.6	11.29	7.85	0.00	3.65	1.00	74.64	30.9
1230	40.0	11.36	8.00	0.00	3.93	1.06	72.43	33.1
1425	40.0	11.36	7.97	-1.00	4.43	1.06	72.34	33.2
1600	40.0	11.36	7.94	-1.00	4.79	1.06	73.11	32.4
1815	42.4	11.36	8.19	-2.00	5.38	1.13	69.34	36.2
1944	44.9	11.36	8.42	-1.00	5.72	1.19	67.58	38.0

TABLE III (Contd.)

4/ 28/ 67   RUN NO. 25   75 MWD
ROD NO. 11 CAL. 1.010
ROD NO. 4 CAL. .930

TIME	MW	R 11	R 4	TEMP	BU	RBNK	EXCESS	PRD
1740	.9	8.78	7.75	0.00	0.00	.02	96.27	0.0
2015	44.9	11.00	8.90	0.00	.35	1.19	59.39	36.8

5/ 19/ 67   RUN NO. 25   262 MWD
ROD NO. 4 CAL. .900

TIME	MW	R 4	R 0	TEMP	BU	RBNK	EXCESS	PRD
845	.6	5.15	0.00	0.00	0.00	0.00	89.46	.8
920	10.7	6.41	0.00	0.00	.02	-.11	73.22	17.0
1015	15.6	6.77	0.00	0.00	.09	-.17	68.36	21.8
1100	20.5	6.88	0.00	0.00	.18	-.22	66.86	23.3
1125	25.4	7.10	0.00	0.00	.24	-.28	63.92	26.3
1150	30.3	7.17	0.00	0.00	.39	-.33	63.15	27.1
1200	35.1	7.42	0.00	0.00	.43	-.39	60.03	30.2
1235	40.0	7.62	0.00	0.00	.55	-.44	57.52	32.7
1315	44.9	8.05	0.00	0.00	.73	-.49	52.00	38.2
1600	44.9	8.15	0.00	0.00	1.18	-.49	51.12	39.1

5/ 22/ 67   RUN NO. 25   285 MWD
ROD NO. 8 CAL. 1.020

TIME	MW	R 8	R 0	TEMP	BU	RBNK	EXCESS	PRD
1945	.5	5.29	0.00	0.00	0.00	0.00	99.39	1.0
2120	10.7	6.16	0.00	-1.00	.03	-.14	85.70	14.6
2133	20.5	6.52	0.00	0.00	.05	-.27	81.21	19.1
2205	25.4	6.66	0.00	0.00	.18	-.33	79.13	21.2
2220	30.3	6.74	0.00	0.00	.23	-.40	77.87	22.5
2252	37.6	6.98	0.00	0.00	.29	-.50	73.97	26.4
2400	44.9	7.50	0.00	0.00	.56	-.59	66.79	33.5

TABLE III (Contd.)

7/ 5/ 67   RUN NO. 25   939 MWD
ROD NO. 8 CAL. 1.020

TIME	MW	R 8	R O	TEMP	BU	RBNK	EXCESS	PRD
2049	.5	7.45	0.00	1.00	0.00	-.01	68.54	1.0
2338	1.0	7.44	0.00	0.00	.01	-.02	67.68	1.8
2400	1.9	7.44	0.00	0.00	.01	-.05	67.65	1.8
100	2.4	7.63	0.00	0.00	.02	-.07	64.87	4.6
211	4.9	8.05	0.00	0.00	.06	-.14	58.59	10.9
404	7.4	8.13	0.00	0.00	.13	-.21	57.38	12.1
518	10.7	8.23	0.00	0.00	.19	-.30	55.84	13.6
622	13.1	8.33	0.00	0.00	.29	-.37	54.36	15.1
726	15.6	8.43	0.00	0.00	.38	-.45	52.87	16.6
800	15.6	8.43	0.00	0.00	.43	-.45	52.92	16.6
1430	20.5	8.64	0.00	0.00	1.05	-.59	50.26	19.2
1545	25.4	8.82	0.00	0.00	1.22	-.73	47.61	21.9
1600	25.4	8.82	0.00	0.00	1.24	-.73	47.63	21.9
1650	25.4	8.84	0.00	0.00	1.38	-.73	47.48	22.0
1810	30.3	8.96	0.00	0.00	1.60	-.87	45.80	23.7
1930	35.1	9.34	0.00	-1.00	1.84	-1.01	39.45	30.0
2135	35.1	9.52	0.00	-.50	2.31	-1.01	37.93	31.6
2300	40.0	9.81	0.00	0.00	2.71	-1.15	34.83	34.7
2400	44.9	10.17	0.00	-1.00	2.96	-1.29	29.42	40.1

7/ 23/ 67 RUN NO. 25   1541 MWD
ROD NO. 8 CAL. 1.020

TIME	MW	R 8	R O	TEMP	BU	RBNK	EXCESS	PRD
800	.9	6.13	0.00	0.00	0.00	-.12	87.13	0.0
844	10.7	7.03	0.00	0.00	.01	-1.41	72.04	15.0
1145	20.5	7.15	0.00	0.00	.21	-2.68	69.31	17.8
1334	30.3	7.28	0.00	0.00	.33	-3.97	66.34	20.7
1449	37.6	7.61	0.00	0.00	.57	-4.93	60.86	26.2
1515	41.5	7.88	0.00	0.00	.80	-5.44	56.58	30.5
1600	44.9	8.24	0.00	0.00	1.01	-5.89	50.92	36.2
1628	44.9	8.28	0.00	0.00	1.14	-5.89	50.45	36.6

TABLE III (Contd.)

8/ 17/ 67 RUN NO. 25   1552 MWD
ROD NO. 8 CAL. 1.020

TIME	MW	R 8	R 0	TEMP	BU	RBNK	EXCESS	PRD
2400	.5	5.60	0.00	0.00	0.00	-.06	94.88	1.0
45	7.4	6.54	0.00	.50	.01	-.98	80.65	15.2
150	15.6	6.67	0.00	0.00	.07	-2.05	77.15	18.7
220	20.5	6.76	0.00	0.00	.17	-2.68	75.21	20.6
308	25.4	6.83	0.00	0.00	.33	-3.33	73.63	22.2
349	30.3	6.94	0.00	1.00	.45	-3.97	72.32	23.5
417	35.1	7.03	0.00	-1.00	.55	-4.61	68.38	27.5
452	40.0	7.40	0.00	-.50	.69	-5.25	63.21	32.6
530	44.9	7.72	0.00	0.00	.82	-5.89	58.53	37.3
623	30.3	7.28	0.00	-1.00	.91	-3.97	65.92	29.9
640	20.5	7.16	0.00	0.00	.94	-2.68	69.90	25.9
715	10.7	6.88	0.00	0.00	.95	-1.41	75.37	20.5
735	7.4	6.83	0.00	1.00	.96	-.98	77.61	18.2
800	7.4	6.82	0.00	1.00	.98	-.98	77.79	18.0
937	.5	5.81	0.00	.50	1.06	-.06	93.41	2.4

9/ 25/ 67 RUN NO. 2601   0 MWD
ROD NO. 8 CAL. 1.022

TIME	MW	R 8	R 0	TEMP	BU	RBNK	EXCESS	PRD
1308	.5	5.64	0.00	0.00	0.00	-.04	94.50	1.0
1504	10.7	6.66	0.00	.10	.09	-1.06	78.56	16.9
1902	15.7	6.79	0.00	.25	.30	-1.56	76.40	19.1
2010	20.7	6.90	0.00	0.00	.45	-2.05	74.06	21.4
2130	25.3	7.05	0.00	0.00	.60	-2.51	71.40	24.1
2210	30.1	7.22	0.00	.40	.80	-2.98	69.17	26.3
2252	35.4	7.45	0.00	0.00	.85	-3.56	64.97	30.5
2335	39.7	7.73	0.00	0.00	1.00	-3.93	60.65	34.8
16	44.9	8.16	0.00	.25	1.20	-4.44	54.13	41.3
315	39.8	7.98	0.00	0.00	1.89	-3.94	57.78	37.7
426	30.4	7.54	0.00	0.00	2.48	-3.01	65.84	29.6
635	20.7	7.29	0.00	0.00	2.74	-2.05	70.66	24.8
845	10.7	7.03	0.00	.50	3.02	-1.06	76.03	19.4
945	0.0	5.77	0.00	.50	3.07	0.00	96.24	-.7

9/ 26/ 67 RUN NO. 2601   19 MWD
ROD NO. 8 CAL. 1.022

TIME	MW	R 8	R 0	TEMP	BU	RBNK	EXCESS	PRD
1300	0.0	5.71	0.00	0.00	0.00	0.00	93.54	0.0
1400	10.8	6.90	0.00	-.50	0.00	-1.07	74.09	19.4
1630	15.7	7.08	0.00	0.00	.15	-1.56	71.49	22.0
1700	25.3	7.34	0.00	0.00	.30	-2.50	67.06	26.4
1835	35.9	7.62	0.00	1.00	.60	-3.56	63.24	30.2
1950	35.9	7.66	0.00	0.00	.75	-3.56	61.80	31.7
2012	45.0	8.29	0.00	1.00	.90	-4.45	52.60	40.9

TABLE III (Contd.)

9/ 29/ 67   RUN NO. 2601   65 MWD
ROD NO.   8   CAL. 1.022

TIME	MW	R 8	R 0	TEMP	BU	RBNK	EXCESS	PRD
120	0.0	6.07	0.00	0.00	0.00	0.00	88.30	0.0
230	6.1	6.91	0.00	-.20	0.00	-.60	74.69	13.6
335	10.9	7.22	0.00	-.50	.15	-1.08	69.52	18.7
507	15.9	7.40	0.00	-.20	.30	-1.58	66.93	21.3
540	20.6	7.56	0.00	.50	.30	-2.04	64.84	23.4
630	25.4	7.62	0.00	-.20	.45	-2.52	62.93	25.3
740	30.3	7.74	0.00	-.20	.60	-3.00	60.83	27.4
903	35.9	8.04	0.00	-.30	1.05	-3.56	56.13	32.1
1032	39.9	8.38	0.00	.30	1.35	-3.95	51.49	36.8
1050	44.9	8.78	0.00	0.00	1.50	-4.45	44.86	43.4
1740	44.9	9.06	0.00	.80	3.30	-4.45	43.35	44.9
1840	30.6	8.24	0.00	-1.00	3.45	-3.03	55.33	32.9
1910	20.5	8.08	0.00	0.00	3.45	-2.03	59.75	28.5
2030	10.7	7.78	0.00	.20	3.60	-1.06	65.57	22.7
2205	0.0	6.74	0.00	3.00	3.60	0.00	84.80	3.5

10/ 14/ 67   RUN NO. 2602   89 MWD
ROD NO.   5   CAL. 1.077

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
400	0.0	4.50	0.00	0.00	0.00	0.00	97.60	0.0
1100	10.8	5.85	0.00	.53	.15	.10	80.50	17.1
1230	15.7	5.97	0.00	0.00	.22	.15	78.48	19.1
1315	20.6	6.17	0.00	.13	.30	.20	76.05	21.5
1424	25.2	6.30	0.00	-.26	.60	.25	74.26	23.3
1510	30.2	6.50	0.00	0.00	.72	.30	72.07	25.5
1745	36.0	6.94	0.00	.10	1.05	.36	67.16	30.4
1920	40.2	7.29	0.00	.30	1.35	.40	63.38	34.2
2020	45.0	7.75	0.00	-.10	1.65	.45	57.06	40.5
200	44.9	7.97	0.00	0.00	3.30	.44	55.80	41.8
210	39.9	7.68	0.00	.20	3.31	.39	59.93	37.6
300	35.9	7.47	0.00	.50	3.45	.35	63.19	34.4
330	30.3	7.20	0.00	.90	3.60	.30	67.34	30.2
400	25.4	6.94	0.00	.10	3.63	.25	69.64	27.9
445	20.7	6.85	0.00	1.00	3.75	.20	71.53	26.0
505	15.9	6.59	0.00	0.00	3.79	.15	73.83	23.7
610	10.9	6.30	0.00	0.00	3.81	.10	77.59	20.0
720	0.0	4.84	0.00	.60	3.82	0.00	97.65	0.0

TABLE III (Contd.)

10/ 15/ 67   RUN NO. 2602   114 MWD
ROD NO.   5   CAL. 1.077

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1951	0.0	4.66	0.00	-.10	0.00	0.00	95.45	0.0
2045	10.8	5.98	0.00	-.40	.15	.10	77.82	17.6
2124	15.9	6.17	0.00	-.60	.15	.15	75.12	20.3
2225	20.7	6.33	0.00	-.30	.30	.20	73.49	21.9
2325	25.2	6.53	0.00	.30	.30	.25	71.51	23.9
130	30.6	6.74	0.00	-.20	.60	.30	68.66	26.7
200	36.2	7.06	0.00	0.00	.75	.36	65.52	29.9
245	40.0	7.48	0.00	-.20	.90	.40	59.85	35.6
330	45.4	8.03	0.00	0.00	1.20	.45	52.88	42.5

10/ 17/ 67   RUN NO. 2602   177 MWD
ROD NO.   5   CAL. 1.077

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1940	0.0	5.50	0.00	.40	0.00	0.00	84.84	0.0
2115	11.0	6.77	0.00	.90	0.00	.11	68.59	16.2
2146	16.0	6.80	0.00	-1.00	.15	.16	66.51	18.3
2230	20.5	6.98	0.00	-.10	.15	.20	65.61	19.2
2247	25.1	7.14	0.00	.10	.30	.25	64.00	20.8
50	30.3	7.42	0.00	1.00	.60	.30	61.47	23.3
210	36.4	7.80	0.00	1.00	.75	.36	56.49	28.3
240	39.9	8.08	0.00	0.00	.90	.39	51.85	32.9
340	44.9	8.77	0.00	1.30	1.20	.44	44.29	40.5

10/ 20/ 67   RUN NO. 2602   238 MWD
ROD NO.   5   CAL. 1.077

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1323	.9	6.24	0.00	-.30	0.00	0.00	74.18	.5
145	30.2	8.44	0.00	.30	1.50	.30	47.80	26.8
230	37.5	8.80	0.00	0.00	1.80	.37	43.13	31.5
330	44.9	9.57	0.00	1.30	2.10	.44	35.29	39.3

TABLE III (Contd.)

10/ 27/ 67   RUN NO. 2602   546 MWD
ROD NO.   5   CAL. 1.077

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1800	0.0	6.25	0.00	.20	0.00	0.00	74.54	0.0
2020	10.7	7.52	0.00	.50	.15	-.19	58.66	15.8
2100	15.7	7.58	0.00	.30	.22	-.28	57.62	16.9
2145	20.6	7.66	0.00	.30	.30	-.37	56.47	18.0
2240	25.3	7.84	0.00	.60	.37	-.45	54.34	20.1
2317	30.3	7.96	0.00	-.10	.45	-.54	51.99	22.5
30	36.0	8.41	0.00	-.10	.75	-.64	46.10	28.4
130	40.2	8.84	0.00	.40	.90	-.72	41.01	33.5
250	44.8	9.30	0.00	-.40	1.35	-.80	34.81	39.7

11/ 18/ 67   RUN NO. 2602   1056 MWD
ROD NO.   5   CAL. 1.063

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
930	.5	4.91	0.00	1.00	0.00	-.04	92.06	1.0
1154	10.0	6.07	0.00	-.90	0.00	-.90	73.95	19.1
1324	15.2	6.22	0.00	.20	.15	-1.37	72.75	20.3
1428	20.3	6.22	0.00	.50	.15	-1.83	72.59	20.4
1503	25.3	6.27	0.00	-.35	.30	-2.28	70.78	22.2
1549	30.0	6.46	0.00	-.17	.45	-2.70	68.21	24.8
1700	35.9	6.98	0.00	1.19	.75	-3.23	63.21	29.8
1740	40.0	7.32	0.00	.80	.90	-3.60	58.22	34.8
1830	45.0	7.81	0.00	.30	1.05	-4.05	50.83	42.2
2250	44.9	8.81	0.00	.10	7.95	-4.04	44.30	48.7
2320	40.0	8.45	0.00	.10	8.10	-3.60	49.57	43.4
20	30.6	7.78	0.00	-.10	8.40	-2.75	59.48	33.5
100	20.3	7.60	0.00	.90	8.40	-1.83	63.83	29.2
240	10.7	7.29	0.00	-.90	8.55	-.96	67.21	25.8
315	0.0	5.88	0.00	0.00	8.55	0.00	86.83	6.2

11/ 24/ 67   RUN NO. 2603   1119 MWD
ROD NO.   7   CAL. 1.070

TIME	MW	R 7	R 0	TEMP	BU	RBNK	EXCESS	PRD
900	0.0	7.03	0.00	.50	0.00	0.00	64.89	0.0
905	5.8	7.98	0.00	1.00	0.00	-.07	52.49	12.3
1025	10.7	8.41	0.00	.21	0.00	-.14	45.86	19.0
1200	16.0	8.40	0.00	-.60	.15	-.21	45.26	19.6
1230	15.8	8.48	0.00	.15	.15	-.21	44.95	19.9
1345	20.7	8.55	0.00	-.10	.30	-.28	43.86	21.0
1450	25.3	8.76	0.00	.60	.45	-.34	41.91	22.9

TABLE III (Contd.)

11/ 25/ 67   RUN NO. 2603   1130 MWD
ROD NO.   7 CAL. 1.070

TIME	MW	R 7	R 0	TEMP	BU	RBNK	EXCESS	PRD
2150	0.0	6.30	0.00	.30	0.00	0.00	73.49	0.0
2350	6.0	7.23	0.00	1.00	0.00	-.08	62.65	10.8
250	11.1	7.55	0.00	.58	.15	-.15	57.89	15.6
835	15.7	7.55	0.00	-.10	.45	-.21	57.55	15.9
925	20.5	7.80	0.00	.55	.60	-.27	54.89	18.6
1017	25.3	7.83	0.00	0.00	.75	-.34	54.02	19.4
1117	30.3	8.13	0.00	.21	.90	-.41	50.25	23.2
1222	35.9	8.55	0.00	.16	1.05	-.48	44.67	28.8
1334	39.9	8.89	0.00	.10	1.35	-.54	40.44	33.0
1423	44.7	9.39	0.00	.37	1.65	-.60	34.76	38.7

11/ 30/ 67   RUN NO. 2603   1279 MWD
ROD NO.   5 CAL. 1.034

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
250	0.0	5.65	0.00	0.00	0.00	0.00	79.13	0.0
440	5.8	6.64	0.00	.46	0.00	-.24	66.68	12.4
511	10.9	6.82	0.00	-.54	.15	-.46	63.42	15.7
1200	15.9	6.72	0.00	.78	.60	-.67	66.19	12.9
1325	20.9	6.81	0.00	1.40	.75	-.89	65.66	13.4
1500	25.5	6.86	0.00	.50	1.05	-1.08	64.26	14.8
1620	30.3	7.14	0.00	.30	1.35	-1.29	61.17	17.9
1703	35.9	7.47	0.00	.10	1.50	-1.52	56.60	22.5
1740	40.0	7.75	0.00	-.20	1.65	-1.70	52.60	26.5
1826	44.9	8.29	0.00	-.20	1.80	-1.91	45.49	33.6

12/ 11/ 67   RUN NO. 2603   1731 MWD
ROD NO.   5 CAL. .978

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1630	0.0	4.41	0.00	0.00	0.00	0.00	89.66	0.0
1902	10.9	5.69	0.00	.50	0.00	-1.95	72.90	16.7
2017	16.0	5.56	0.00	.10	.15	-2.85	73.34	16.3
2125	20.6	5.43	0.00	.21	.30	-3.68	74.36	15.2
2220	23.0	5.38	0.00	-.33	.45	-4.10	74.17	15.4
2300	25.2	5.40	0.00	0.00	.58	-4.49	73.99	15.6

TABLE III (Contd.)

2/ 5/ 68   RUN NO. 2701   O MWD
ROD NO. 5 CAL. 1.050
ROD NO. 4 CAL. .879

TIME	MW	R 5	R 4	TEMP	BU	RBNK	EXCESS	PRD
800	.5	4.88	12.00	.50	0.00	-.02	100.71	0.0
1630	2.4	5.28	12.00	.20	0.00	-.10	95.16	5.5
1945	5.6	5.78	12.00	-.20	.15	-.25	88.19	12.5
200	11.0	6.40	12.00	.10	.30	-.49	80.21	20.4
430	16.0	6.77	12.00	1.25	.60	-.71	76.81	23.9
700	20.8	6.72	12.00	-.10	.90	-.93	76.12	24.5
930	25.6	6.87	12.00	-.54	1.35	-1.14	74.07	26.6
1130	30.7	7.08	12.00	-.18	1.65	-1.37	72.44	28.2
1330	36.4	7.44	12.00	.05	2.10	-1.63	68.09	32.6
1544	40.4	7.77	12.00	-.84	2.70	-1.81	63.24	37.4
1915	44.9	8.38	12.00	-.60	4.05	-2.01	56.61	44.0
1040	43.2	12.00	8.72	.56	7.95	-1.93	57.87	42.8
1300	38.7	12.00	8.29	-.60	8.40	-1.73	62.90	37.8
1514	29.6	12.00	7.78	-.33	8.85	-1.32	70.68	30.0
1800	19.9	12.00	7.43	-.59	9.15	-.89	75.63	25.0
2035	9.9	12.00	7.09	-.52	9.45	-.44	80.57	20.1
2240	1.1	5.45	12.00	-.12	9.45	-.05	102.12	-1.4
30	0.0	12.00	5.32	0.00	9.45	0.00	104.24	-3.5

2/ 8/ 68   RUN NO. 2701   63 MWD
ROD NO. 5 CAL. 1.054

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
210	0.0	5.27	0.00	0.00	0.00	0.00	85.67	0.0
331	5.8	6.28	0.00	-.83	0.00	-.26	71.15	14.5
450	10.8	7.03	0.00	.82	0.00	-.48	63.71	21.9
600	15.7	7.14	0.00	-.42	.15	-.70	60.95	24.7
730	20.6	7.26	0.00	-.12	.30	-.92	59.56	26.1
900	25.3	7.32	0.00	-.76	.45	-1.13	58.17	27.4
1030	30.3	7.47	0.00	-.82	.75	-1.36	56.19	29.4
1230	36.3	7.84	0.00	-.90	1.20	-1.63	51.34	34.3
1400	40.1	8.21	0.00	-.46	1.65	-1.80	47.05	38.6
1530	44.9	8.69	0.00	-.45	2.10	-2.01	41.01	44.6

TABLE III (Contd.)

2/ 23/ 68   RUN NO. 2701   96 MWD
ROD NO.   5   CAL. 1.043

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1632	0.0	5.28	0.00	.10	0.00	0.00	84.64	0.0
1909	4.7	6.16	0.00	-.40	.15	-.21	72.61	12.0
2044	9.6	6.84	0.00	-.03	.21	-.43	64.32	20.3
2244	14.5	7.02	0.00	-.21	.30	-.65	62.30	22.3
4	19.0	7.16	0.00	-.03	.45	-.85	60.57	24.0
230	25.4	7.25	0.00	.13	.75	-1.14	59.59	25.0
400	29.0	7.42	0.00	.18	1.05	-1.30	57.59	27.0
600	33.6	7.69	0.00	-.07	1.50	-1.50	53.99	30.6
745	38.6	8.06	0.00	.13	1.95	-1.73	49.50	35.1
1049	43.8	8.68	0.00	-.10	2.85	-1.96	41.96	42.6

2/ 28/ 68   RUN NO. 2701   279 MWD
ROD NO.   5   CAL. 1.043

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
525	.5	5.06	0.00	.03	0.00	-.03	87.46	1.0
235	10.8	6.97	0.00	.10	0.00	-.85	62.61	25.8
115	15.8	7.14	0.00	-.10	-.15	-1.24	59.75	28.7
3	20.3	7.35	0.00	.60	-.30	-1.60	57.30	31.1
2232	30.2	7.50	0.00	-.42	-.60	-2.38	53.23	35.2
2105	39.5	8.12	0.00	.50	-.75	-3.11	45.07	43.3
2000	45.0	8.41	0.00	.10	-1.05	-3.54	40.15	48.3

3/ 1/ 68   RUN NO. 2702   283 MWD
ROD NO.   5   CAL. 1.078

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
930	0.0	1.30	0.00	.20	0.00	0.00	131.07	0.0
1220	4.7	2.63	0.00	.20	0.00	-.21	118.95	12.1
1445	11.3	3.49	0.00	.45	.15	-.51	109.93	21.1
1614	16.2	3.58	0.00	-.02	.30	-.72	108.36	22.7
1759	20.9	3.57	0.00	-.71	.60	-.94	107.87	23.1
1954	25.6	3.81	0.00	-.02	.75	-1.15	105.73	25.3
2135	30.0	4.02	0.00	-.38	1.20	-1.35	103.11	27.9
2325	35.4	4.41	0.00	-.22	1.50	-1.59	98.52	32.5
110	39.0	4.80	0.00	-.11	2.10	-1.75	94.07	37.0
300	43.5	5.32	0.00	.38	2.55	-1.95	87.92	43.1

TABLE III (Contd.)

3/ 7/ 68   RUN NO. 2703   463 MWD
ROD NO. 5   CAL. 1.044

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
2200	0.0	3.70	0.00	.20	0.00	0.00	104.24	0.0
20	4.8	4.67	0.00	-.20	.15	-.38	92.07	12.1
230	10.9	5.34	0.00	-.40	.30	-.86	82.98	21.2
340	15.8	5.51	0.00	.10	.45	-1.25	81.02	23.2
515	20.2	5.55	0.00	0.00	.60	-1.59	80.21	24.0
645	25.1	5.59	0.00	-.25	.75	-1.97	79.20	25.0
810	29.9	5.73	0.00	-.20	1.05	-2.35	77.34	26.8
1024	35.3	6.07	0.00	.10	1.65	-2.77	73.37	30.8
1210	39.3	6.48	0.00	1.10	1.95	-3.09	69.08	35.1
1340	43.8	6.88	0.00	.40	2.40	-3.44	63.52	40.7

3/ 30/ 68   RUN NO. 2704   539 MWD
ROD NO. 5   CAL. 1.055

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
845	0.0	5.22	0.00	.29	0.00	0.00	86.69	0.0
1310	6.2	6.37	0.00	-.10	.15	.07	71.39	15.2
1525	11.3	6.90	0.00	.10	.15	.14	64.99	21.6
1745	15.9	6.97	0.00	-1.20	.45	.19	63.54	23.1
1930	22.4	7.16	0.00	-.30	.60	.27	62.37	24.3
2115	25.0	7.30	0.00	-.02	.90	.31	61.13	25.5
2245	29.6	7.53	0.00	.10	1.05	.36	58.40	28.2
15	35.3	7.87	0.00	-.11	1.50	.43	54.15	32.5
205	38.9	8.30	0.00	.18	1.80	.48	49.06	37.6
345	43.5	8.80	0.00	.20	2.25	.54	43.11	43.5

4/ 9/ 68   RUN NO. 2705   825 MWD
ROD NO. 5   CAL. .981

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1600	0.0	4.22	0.00	-.10	0.00	0.00	92.01	0.0
1805	5.7	5.43	0.00	-.50	0.00	-.01	77.28	14.7
1955	10.7	6.19	0.00	-.30	.15	-.02	68.29	23.7
2125	16.0	6.52	0.00	-.30	.30	-.03	64.46	27.5
2255	21.2	6.64	0.00	-.60	.45	-.04	62.88	29.1
25	25.7	6.85	0.00	.20	.60	-.04	61.40	30.6
206	30.9	7.11	0.00	.10	.90	-.05	59.02	32.9
330	36.6	7.48	0.00	.10	1.20	-.07	54.75	37.2
455	40.1	7.78	0.00	-.20	1.65	-.07	51.16	40.8
635	44.9	8.30	0.00	-.10	2.10	-.08	45.25	46.7

TABLE III (Contd.)

4/ 14/ 68   RUN NO. 2706   907 MWD
ROD NO. 5 CAL. .916

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
250	0.0	5.91	0.00	-.15	0.00	0.00	66.95	0.0
459	6.1	7.15	0.00	-.70	0.00	-.38	52.68	14.2
650	10.8	7.76	0.00	.13	0.00	-.66	46.17	20.7
815	16.0	7.91	0.00	-.64	.15	-.99	43.48	23.4
1030	20.8	7.97	0.00	-.24	.45	-1.28	43.19	23.7
1700	25.6	8.17	0.00	.21	1.20	-1.58	41.70	25.2
1900	30.6	8.38	0.00	.20	1.50	-1.89	39.35	27.5
2049	35.9	8.72	0.00	.26	1.95	-2.22	35.62	31.3
2300	39.8	9.09	0.00	.02	2.55	-2.45	31.80	35.1
124	44.9	9.62	0.00	-.14	3.15	-2.77	26.47	40.4

4/ 18/ 68   RUN NO. 2707   972 MWD
ROD NO. 5 CAL. .922

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
225	0.0	4.33	0.00	.20	0.00	0.00	85.59	0.0
447	5.9	5.61	0.00	-.01	0.00	.07	71.09	14.5
615	10.9	6.35	0.00	1.10	.15	.13	63.90	21.6
745	16.1	6.56	0.00	.20	.22	.20	60.78	24.8
1000	21.3	6.71	0.00	.44	.45	.26	59.66	25.9
1145	25.9	6.83	0.00	.15	.75	.32	58.44	27.1
1315	31.1	7.11	0.00	.05	1.20	.38	56.22	29.3
1515	36.3	7.46	0.00	.14	1.50	.45	52.62	32.9
1730	39.8	7.78	0.00	.50	1.80	.49	49.58	36.0
1749	45.0	8.18	0.00	-.70	2.25	.56	44.23	41.3

4/ 26/ 68   RUN NO. 2708   1020 MWD
ROD NO. 5 CAL. 1.019

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
2019	0.0	5.05	0.00	-.08	0.00	0.00	85.50	0.0
2314	6.3	6.22	0.00	-.25	0.00	-.50	69.96	15.5
1245	10.8	6.73	0.00	0.00	.30	-.85	63.86	21.6
1445	15.9	7.00	0.00	.30	.40	-1.25	61.14	24.3
1714	20.4	7.08	0.00	.20	.75	-1.60	60.03	25.4
1920	25.5	7.21	0.00	.16	1.05	-2.01	58.24	27.2
2105	30.6	7.34	0.00	-.20	1.35	-2.41	56.12	29.3
2250	36.4	7.67	0.00	-.15	1.80	-2.86	51.91	33.5
140	39.6	7.98	0.00	-.01	2.40	-3.11	48.39	37.1
450	44.1	8.33	0.00	-.05	3.00	-3.46	44.11	41.3

TABLE III (Contd.)

```
        5/  3/ 68   RUN NO.  2709    1225 MWD
              ROD NO.  5  CAL. 1.020
```

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1835	0.0	5.09	0.00	.50	0.00	0.00	85.67	0.0
2055	5.3	6.09	0.00	-.77	0.00	-.08	71.47	14.1
2300	10.3	6.90	0.00	.41	.15	-.16	62.84	22.8
100	15.8	7.14	0.00	-.38	.30	-.25	59.65	26.0
230	20.8	7.39	0.00	.04	.45	-.33	56.95	28.7
400	26.1	7.43	0.00	-.44	.75	-.42	56.17	29.5
545	30.8	7.66	0.00	.05	1.05	-.50	53.91	31.7
700	36.7	7.95	0.00	.10	1.35	-.59	50.41	35.2
834	40.5	8.28	0.00	0.00	1.65	-.65	46.30	39.3
1004	45.4	8.74	0.00	0.00	2.10	-.73	40.89	44.7

```
        5/  8/ 68   RUN NO.  2801       0 MWD
              ROD NO.  5  CAL. 1.060
```

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1025	0.0	6.64	0.00	.20	0.00	0.00	68.34	1.5
1440	6.3	7.69	0.00	-.10	0.00	-.10	54.79	15.0
1640	11.3	8.37	0.00	.05	0.00	-.18	45.76	24.0
1800	16.3	8.66	0.00	.02	.15	-.26	42.01	27.8
2125	21.2	8.80	0.00	.14	.45	-.34	40.48	29.3
2300	26.0	8.92	0.00	-.08	.75	-.42	39.03	30.8
245	30.8	9.17	0.00	.20	1.05	-.49	36.44	33.3
430	36.2	9.46	0.00	.10	1.50	-.58	33.23	36.6
610	39.8	9.77	0.00	-.40	1.80	-.64	29.44	40.3
845	44.9	10.36	0.00	.20	2.85	-.72	24.84	44.9

```
        5/ 13/ 68   RUN NO.  2801     141 MWD
              ROD NO.  5  CAL. 1.060
```

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
2114	.5	4.99	0.00	.20	0.00	-.02	89.99	1.5
1929	15.7	7.36	0.00	.46	0.00	-.74	59.14	32.3
1635	23.0	7.66	0.00	.26	-.30	-1.08	54.27	37.2
1500	30.3	7.85	0.00	.22	-.60	-1.43	51.03	40.4
1335	36.0	8.06	0.00	-.09	-.90	-1.70	47.33	44.1
1144	39.9	8.26	0.00	-.43	-1.20	-1.88	43.84	47.6
1033	44.9	8.58	0.00	1.00	-1.50	-2.11	40.53	50.9

TABLE III (Contd.)

5/ 17/ 68   RUN NO. 2802   151 MWD
ROD NO. 5 CAL. 1.058

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
555	0.0	2.96	0.00	-.50	0.00	0.00	112.95	0.0
755	6.2	4.45	0.00	-.15	0.00	-.10	96.25	16.7
1000	11.1	5.16	0.00	.23	.15	-.18	87.59	25.3
1130	16.1	5.42	0.00	.02	.15	-.26	83.81	29.1
1236	20.9	5.67	0.00	.60	.30	-.34	81.26	31.6
1354	25.8	5.76	0.00	.41	.60	-.41	80.00	32.9
1505	31.0	5.93	0.00	.10	.75	-.50	77.56	35.3
1634	36.4	6.21	0.00	-.30	1.05	-.59	73.71	39.2
1754	39.9	6.51	0.00	.20	1.35	-.64	70.57	42.3
1954	44.9	6.93	0.00	.20	1.80	-.72	65.83	47.1

5/ 21/ 68   RUN NO. 2802   284 MWD
ROD NO. 5 CAL. 1.058

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1830	0.0	4.36	0.00	0.00	0.00	0.00	97.61	0.0
1949	5.6	5.59	0.00	0.00	0.00	-.09	81.67	15.9
2020	10.7	6.26	0.00	0.00	0.00	-.17	72.72	24.8
2050	15.9	6.56	0.00	0.00	0.00	-.25	68.76	28.8
2130	20.8	6.66	0.00	0.00	.07	-.33	67.49	30.1
2150	25.4	6.81	0.00	0.00	.15	-.41	65.63	31.9
2210	30.5	6.96	0.00	0.00	.22	-.49	64.08	33.5
2240	36.2	7.35	0.00	.80	.30	-.58	59.96	37.6
2310	39.8	7.50	0.00	0.00	.45	-.64	57.25	40.3
2330	45.2	7.94	0.00	0.00	.52	-.73	51.32	46.2

5/ 26/ 68   RUN NO. 2802   442 MWD
ROD NO. 5 CAL. 1.058

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
415	.5	3.46	0.00	.58	0.00	-.02	108.69	1.5
144	10.8	5.51	0.00	.38	-.15	-.51	82.42	27.7
2334	20.5	6.06	0.00	-.30	-.30	-.96	73.96	36.2
2214	30.5	6.27	0.00	.10	-.45	-1.44	70.98	39.2
2014	39.8	6.72	0.00	-.20	-.90	-1.87	64.03	46.1
1859	45.1	7.02	0.00	.35	-1.20	-2.12	60.82	49.3

TABLE III (Contd.)

5/ 29/ 68   RUN NO. 2803   451 MWD
ROD NO. 5 CAL. 1.050

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
1905	0.0	4.97	0.00	.20	0.00	0.00	89.42	0.0
2205	6.5	6.22	0.00	-.50	0.00	-.30	72.06	17.3
2400	11.3	6.95	0.00	-.11	.15	-.53	63.44	25.9
129	16.3	7.14	0.00	-.53	.30	-.76	60.76	28.6
300	21.2	7.34	0.00	.50	.45	-1.00	59.07	30.3
420	25.9	7.40	0.00	.13	.75	-1.22	57.99	31.4
559	30.9	7.55	0.00	-.23	.90	-1.45	55.56	33.8
729	35.7	7.95	0.00	.37	1.20	-1.68	50.89	38.5
900	40.4	8.19	0.00	-.60	1.65	-1.90	46.97	42.4
1100	45.0	8.70	0.00	-.60	2.10	-2.12	40.57	48.8

6/ 14/ 68   RUN NO. 2803   1105 MWD
ROD NO. 5 CAL. 1.050

TIME	MW	R 5	R 0	TEMP	BU	RBNK	EXCESS	PRD
630	0.0	5.00	0.00	.20	0.00	0.00	89.04	0.0
500	10.6	7.12	0.00	.30	0.00	-1.24	61.07	27.9
330	20.5	7.54	0.00	.51	0.00	-2.40	54.58	34.4
215	30.2	7.68	0.00	.32	-.15	-3.53	51.24	37.7
20	40.0	8.18	0.00	-.55	-.45	-4.67	42.28	46.7
2330	44.9	8.53	0.00	0.00	-.75	-5.25	37.38	51.6

6/ 27/ 68   RUN NO. 2901   0 MWD
ROD NO. 6 CAL. 1.110

TIME	MW	R 6	R 0	TEMP	BU	RBNK	EXCESS	PRD
1250	0.0	5.07	0.00	-1.00	0.00	0.00	110.59	0.0
1500	6.3	6.26	0.00	0.00	.15	.25	93.20	17.3
1614	11.4	6.88	0.00	-.02	.15	.45	83.11	27.4
1745	16.2	7.20	0.00	.34	.30	.64	78.66	31.9
1910	21.1	7.28	0.00	-.40	.45	.84	77.05	33.5
2030	26.0	7.41	0.00	.50	.60	1.04	76.28	34.3
2140	23.4	7.40	0.00	.23	.75	.93	76.21	34.3
2250	21.0	7.38	0.00	.04	.90	.84	76.39	34.1
19	16.0	7.25	0.00	.08	1.05	.64	78.39	32.1
135	11.1	6.92	0.00	.22	1.20	.44	83.68	26.9
300	6.1	6.14	0.00	-.20	1.20	.24	96.04	14.5
530	0.0	5.00	0.00	0.00	1.20	0.00	113.87	-3.2

TABLE III (Contd.)

6/ 28/ 68   RUN NO. 2901   8 MWD
ROD NO. 6   CAL. 1.110

TIME	MW	R 6	R 0	TEMP	BU	RBNK	EXCESS	PRD
530	0.0	5.00	0.00	0.00	0.00	0.00	112.67	0.0
714	6.1	6.12	0.00	-.10	0.00	.24	95.26	17.4
829	11.0	6.82	0.00	3.00	.15	.44	87.16	25.5
1030	16.2	7.08	0.00	-.52	.30	.65	79.61	33.0
1219	21.4	7.21	0.00	0.00	.45	.85	78.53	34.1
1359	26.0	7.35	0.00	.03	.75	1.04	76.90	35.7
1529	30.8	7.50	0.00	-.27	.90	1.23	74.59	38.0
1710	36.2	7.78	0.00	-.33	1.20	1.44	70.42	42.2
1830	39.7	8.12	0.00	.08	1.50	1.59	65.88	46.7
2025	41.7	8.27	0.00	.03	1.95	1.66	63.89	48.7
2130	39.0	8.18	0.00	.10	2.40	1.56	65.78	46.8
2305	36.0	8.04	0.00	.02	2.70	1.44	68.17	44.4
30	30.5	7.87	0.00	.20	3.00	1.22	71.21	41.4
220	25.3	7.74	0.00	.45	3.30	1.01	73.66	39.0
445	20.8	7.59	0.00	-.16	3.60	.83	75.57	37.1
705	15.9	7.47	0.00	.38	3.75	.63	77.96	34.7
849	11.0	7.04	0.00	-.35	3.75	.44	83.61	29.0
1029	6.0	6.32	0.00	.25	3.90	.24	96.28	16.3
1359	0.0	5.17	0.00	.48	3.90	0.00	114.41	-1.7

6/ 29/ 68   RUN NO. 2901   34 MWD
ROD NO. 6   CAL. 1.110

TIME	MW	R 6	R 0	TEMP	BU	RBNK	EXCESS	PRD
2050	0.0	5.21	0.00	-.50	0.00	0.00	108.83	0.0
2230	6.1	6.34	0.00	.56	.15	.24	92.52	16.3
2350	11.0	6.92	0.00	-.58	.15	.44	81.83	27.0
130	16.2	7.28	0.00	-.11	.30	.65	77.00	31.8
309	20.9	7.42	0.00	-.02	.45	.83	75.25	33.5
500	26.0	7.51	0.00	-.21	.75	1.04	74.14	34.6
645	30.5	7.64	0.00	-.56	1.05	1.22	72.21	36.6
850	36.4	8.03	0.00	.10	1.35	1.45	67.08	41.7
1000	40.3	8.32	0.00	.35	1.80	1.61	63.18	45.6
1130	44.9	8.61	0.00	-1.36	2.25	1.79	57.37	51.4
1300	40.3	8.50	0.00	-.05	2.55	1.61	60.58	48.2
1419	36.2	8.32	0.00	-.10	2.85	1.45	63.62	45.2
1544	30.4	8.10	0.00	0.00	3.15	1.21	67.40	41.4
1719	25.3	7.97	0.00	-.15	3.30	1.01	69.32	39.5
1834	20.7	7.92	0.00	-.03	3.45	.82	70.22	38.6
2044	15.7	7.72	0.00	.12	3.75	.63	73.72	35.1
2210	11.1	7.29	0.00	.20	3.75	.44	80.32	28.5
2335	5.9	6.52	0.00	-.10	3.90	.23	92.66	16.1
230	0.0	5.36	0.00	-.10	3.90	0.00	110.87	-2.0

TABLE III (Contd.)

7/ 5/ 68   RUN NO. 2901   182 MWD
ROD NO. 6   CAL. 1.110

TIME	MW	R 6	R 0	TEMP	BU	RBNK	EXCESS	PRD
1400	0.0	3.60	0.00	-.20	0.00	0.00	133.96	0.0
1215	10.7	5.57	0.00	-.38	0.00	.18	103.60	30.3
1100	20.8	6.17	0.00	.34	0.00	.35	95.01	38.9
1015	31.0	6.31	0.00	-.22	-.15	.53	92.21	41.7
940	40.2	6.67	0.00	-.37	-.30	.68	86.13	47.8
900	45.2	6.92	0.00	.21	-.45	.77	82.35	51.6

7/ 10/ 68   RUN NO. 2902   186 MWD
ROD NO. 6   CAL. 1.077
ROD NO. 10   CAL. 1.002

TIME	MW	R 6	R 10	TEMP	BU	RBNK	EXCESS	PRD
240	0.0	7.24	8.24	-.15	0.00	0.00	129.16	0.0
419	6.3	7.24	9.55	-.02	.15	-.13	110.57	18.5
600	11.1	7.24	10.45	.28	.22	-.23	99.79	29.3
719	16.9	7.24	11.21	.38	.30	-.35	92.22	36.9
915	20.9	7.23	11.50	-.11	.45	-.43	89.46	39.6
1040	25.4	7.39	11.50	0.00	.75	-.53	87.39	41.7
1150	30.5	7.58	11.50	.03	.90	-.63	84.55	44.6
1339	35.9	7.83	11.50	-.11	1.35	-.74	80.85	48.3
1519	39.5	8.08	11.50	-.07	1.65	-.82	77.16	52.0
1615	44.5	8.40	11.50	-.30	2.10	-.93	72.17	56.9
1830	40.7	8.34	11.50	.10	2.55	-.85	74.06	55.0
2000	29.9	7.90	11.50	.06	2.85	-.62	81.54	47.6
2130	22.8	7.60	11.50	.20	3.00	-.47	86.67	42.4
334	0.0	7.24	8.33	-.14	3.60	0.00	131.43	-2.2

7/ 15/ 68   RUN NO. 2903   210 MWD
ROD NO. 6   CAL. 1.030
ROD NO. 11   CAL. 1.060

TIME	MW	R 6	R 11	TEMP	BU	RBNK	EXCESS	PRD
1500	0.0	8.00	7.98	0.00	0.00	0.00	111.10	0.0
1635	5.9	8.00	9.12	-.20	0.00	.06	96.18	14.9
1759	10.8	8.00	9.96	-.30	.15	.12	86.60	24.5
1920	15.9	8.00	10.80	-.20	.22	.18	78.65	32.4
2045	20.9	8.41	11.00	-.10	.45	.23	71.09	40.0
2220	25.5	8.97	11.00	0.00	.60	.29	62.99	48.1
20	20.7	8.46	11.00	.44	.82	.23	71.14	39.9
125	16.0	7.91	11.00	.15	.97	.18	79.41	31.6
310	10.8	7.91	10.01	0.00	1.12	.12	88.70	22.3
445	5.8	7.91	9.38	.09	1.20	.06	95.88	15.2
700	0.0	7.91	7.91	.63	1.20	0.00	115.23	-4.1

TABLE III (Contd.)

7/ 16/ 68   RUN NO. 2903   218 MWD
ROD NO. 6 CAL. 1.030
ROD NO. 11 CAL. 1.060

TIME	MW	R 6	R 11	TEMP	BU	RBNK	EXCESS	PRD
700	0.0	7.91	7.91	.63	0.00	0.00	114.03	0.0
855	7.8	7.91	9.09	.13	0.00	.08	98.26	15.7
1045	11.0	7.91	10.02	.24	.15	.12	87.86	26.1
1200	15.8	7.91	10.92	.31	.30	.17	79.51	34.5
1315	20.8	8.37	11.00	-.06	.45	.23	71.74	42.2
1430	25.4	8.97	11.00	.36	.60	.28	63.35	50.6
1550	30.3	9.58	11.00	.27	.90	.34	54.93	59.1
1715	35.4	10.38	11.00	.40	1.20	.40	45.27	68.7
1900	41.4	11.37	11.00	0.00	1.50	.46	35.17	78.8
2019	38.6	11.06	11.00	0.00	1.95	.43	38.43	75.6
2139	35.4	10.58	11.00	-.10	2.25	.40	43.55	70.4
2205	30.3	9.86	11.00	-.10	2.32	.34	52.25	61.7
2319	25.4	9.22	11.00	0.00	2.40	.28	61.15	52.8
10	20.7	8.77	11.00	.90	2.55	.23	68.75	45.2
110	16.3	8.11	11.00	-.05	2.70	.18	77.91	36.1
215	9.6	8.00	10.23	-.10	2.77	.10	86.61	27.4
340	6.5	8.00	9.20	.02	2.85	.07	98.28	15.7
610	0.0	8.00	7.98	0.00	2.85	0.00	113.95	0.0

7/ 17/ 68   RUN NO. 2903   237 MWD
ROD NO. 6 CAL. 1.030
ROD NO. 11 CAL. 1.060

TIME	MW	R 6	R 11	TEMP	BU	RBNK	EXCESS	PRD
610	0.0	8.00	7.98	0.00	0.00	0.00	111.10	0.0
750	5.9	8.00	9.17	.10	0.00	.06	95.87	15.2
920	11.0	8.00	10.11	0.00	0.00	.12	85.17	25.9
955	15.9	8.00	11.00	-.08	.15	.18	76.99	34.1
1059	20.9	8.55	11.00	0.00	.30	.23	68.92	42.1
1130	25.6	9.06	11.00	-.06	.30	.29	61.31	49.7
1240	30.5	9.68	11.00	-.22	.60	.34	52.79	58.3
1330	35.8	10.55	11.00	.05	.75	.40	42.54	68.5
1430	39.5	11.16	11.00	-.30	.90	.44	36.14	74.9
1550	44.5	12.27	11.00	-.26	1.35	.50	28.03	83.0
1645	44.1	12.35	11.00	-.26	1.50	.50	27.67	83.4
1728	39.4	11.50	11.00	-.13	1.80	.44	34.20	76.9
1808	35.4	10.81	11.00	-.63	1.80	.40	40.11	70.9
1930	30.3	10.06	11.00	-.44	2.10	.34	49.14	61.9
2000	25.2	9.34	11.00	-.89	2.25	.28	58.40	52.7
2040	20.5	8.87	11.00	.18	2.32	.23	66.32	44.7
2108	15.7	8.24	11.00	-.68	2.44	.17	75.04	36.0
2134	11.0	8.00	10.53	-.36	2.40	.12	83.07	28.0
2217	5.9	8.00	9.42	-.85	2.40	.06	94.31	16.7
2335	0.0	8.00	8.23	.10	2.40	0.00	110.26	.8

TABLE III (Contd.)

7/ 22/ 68   RUN NO. 2903   407 MWD
ROD NO.   7 CAL. 1.190

TIME	MW	R 7	R 0	TEMP	BU	RBNK	EXCESS	PRD
1730	0.0	3.89	0.00	.40	0.00	0.00	116.53	0.0
1420	23.1	7.23	0.00	0.00	-.04	-.48	68.12	48.4
1220	30.5	8.12	0.00	-.30	-.34	-.63	53.97	62.5
1114	36.1	8.90	0.00	-.30	-.49	-.75	42.27	74.2
944	40.3	9.46	0.00	-.50	-.79	-.84	34.03	82.4
907	44.9	10.17	0.00	0.00	-.94	-.93	25.54	90.9

7/ 27/ 68   RUN NO. 2904   413 MWD
ROD NO. 11 CAL. 1.050
ROD NO. 6 CAL. 1.060

TIME	MW	R 11	R 6	TEMP	BU	RBNK	EXCESS	PRD
954	0.0	7.36	6.81	-.30	0.00	0.00	138.53	0.0
1134	6.1	8.51	6.81	-.80	.15	-.02	122.93	15.6
1308	10.7	9.38	6.81	.40	.22	-.05	113.39	25.1
1514	16.0	10.17	6.81	-.46	.30	-.07	103.93	34.6
1750	20.6	11.25	6.68	.06	.60	-.10	97.24	41.2
1915	25.4	11.25	7.13	.20	.90	-.12	90.48	48.0
2030	30.2	11.25	7.64	-.10	1.05	-.14	82.73	55.8
2200	36.2	11.25	8.32	-.10	1.35	-.17	72.42	66.1
2330	40.0	11.25	8.82	-.10	1.65	-.19	64.93	73.6
49	44.9	11.25	9.41	-.40	2.10	-.21	56.25	82.2

APPENDIX

Core-loading Diagrams for EBR-II Runs 24-29D

Figures 1-21 show the core-loading diagrams for EBR-II runs 24-29D, and Table IV preceding the figures gives the key for identifying the types of subassemblies shown in each diagram. Core size is defined arbitrarily as the sum of the number of subassemblies in rows 1-5 and the number of full or partial driver subassemblies and of fueled experimental subassemblies in row 6.

TABLE IV. Core-loading Data for Runs 24-29D[a]

B	Depleted uranium
BETH	Beryllium thimble
C	Control rod
D	Driver fuel
OSC	Oscillator rod
P	Half driver fuel, half stainless steel
R	Stainless steel reflector
S	Safety rod
SSCR	Stainless steel control rod
SST	Stainless steel thimble
X	Experimental subassembly

[a]The core-loading diagrams are taken from files maintained by Case[11] and are constructed from original records of subassembly transfers to and from the reactor.
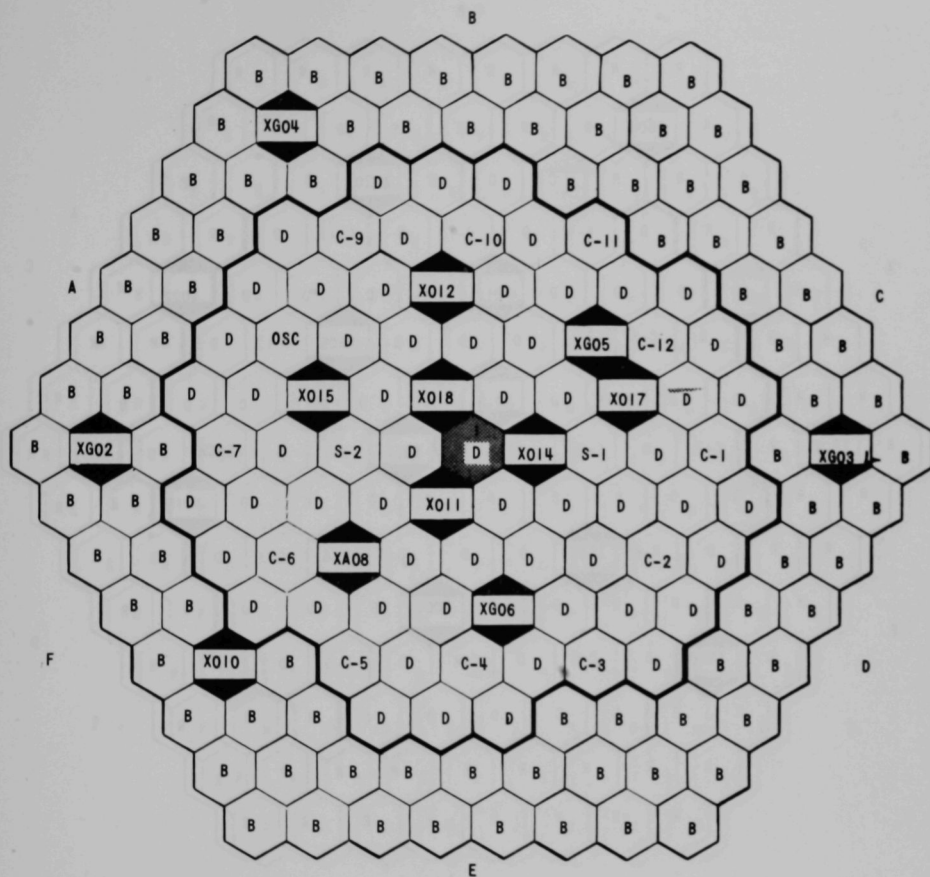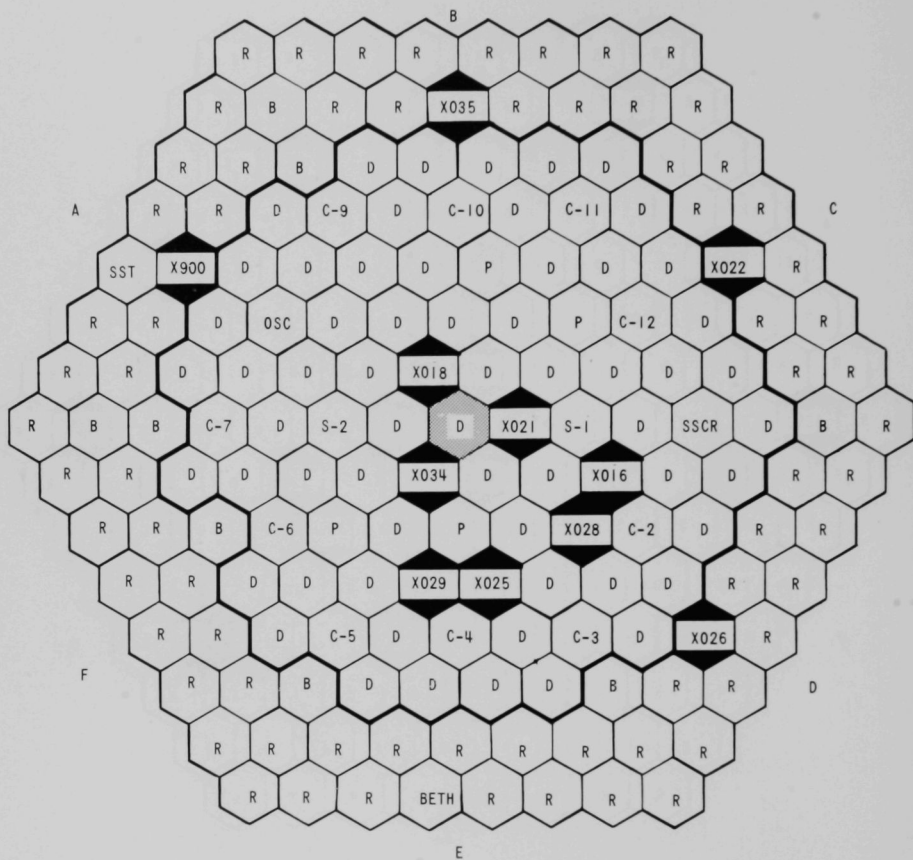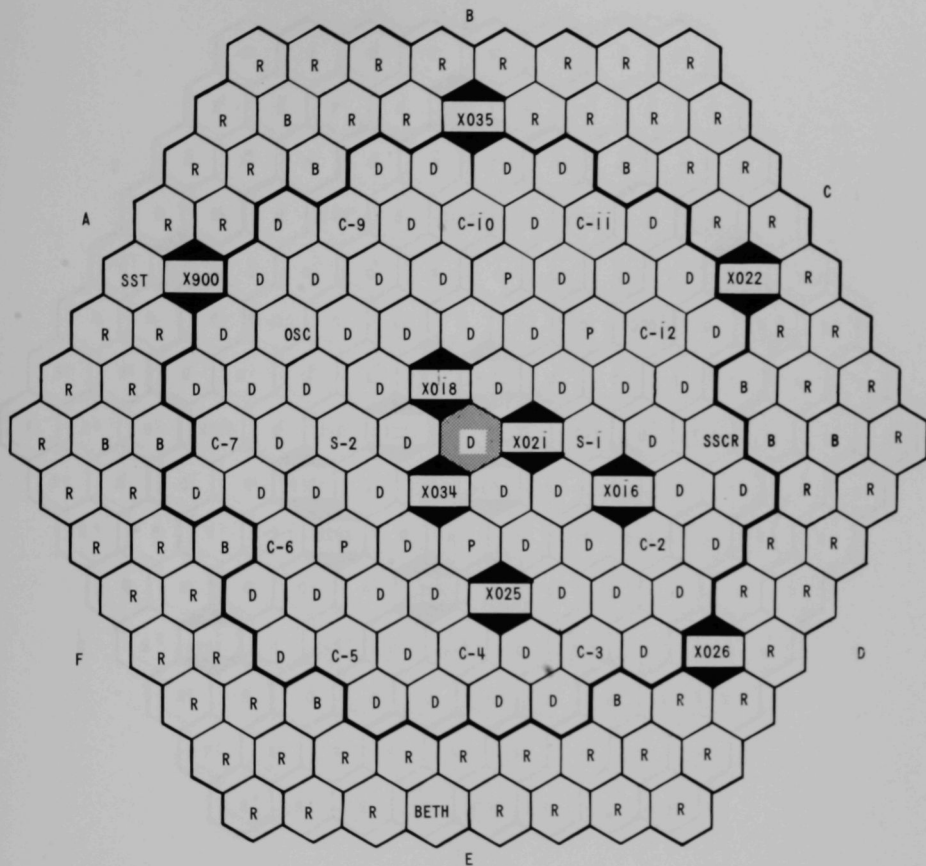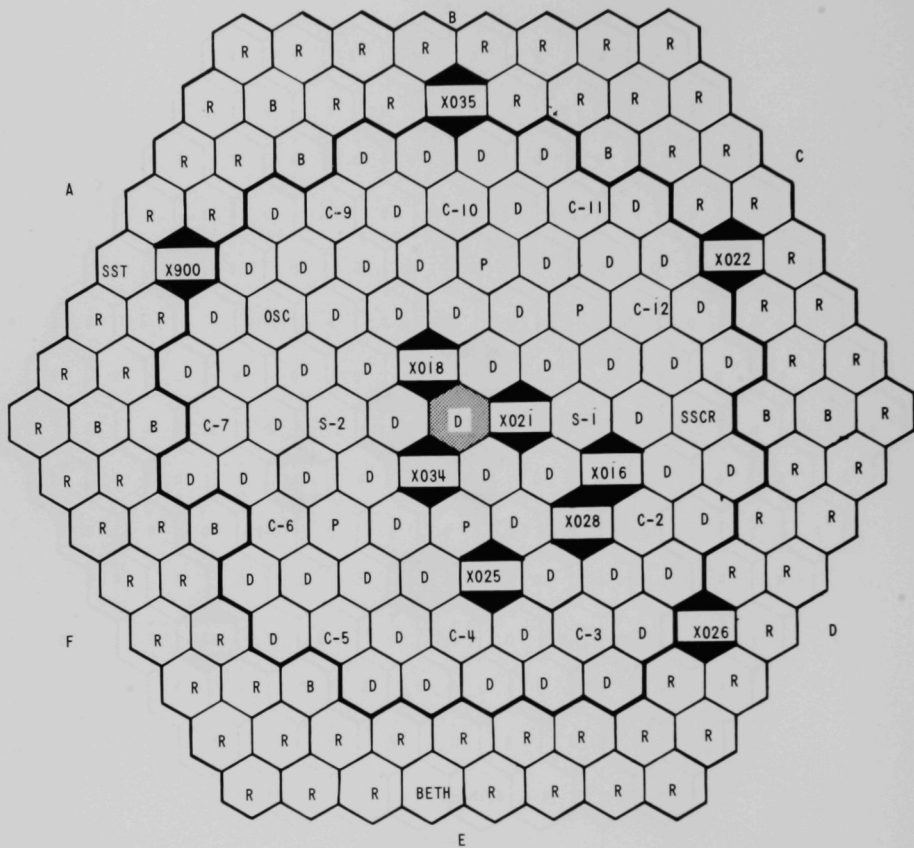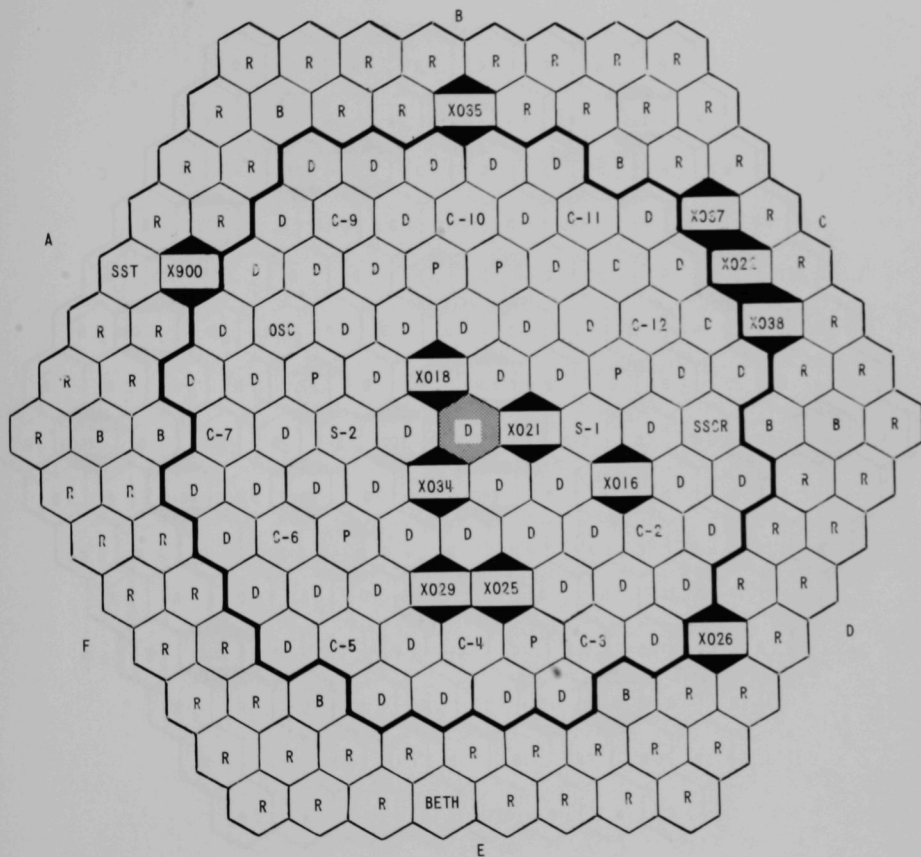
Fig. 1. Core-loading Diagram for EBR-II Run 24, 81-subassembly Core Size (started 12/6/66, ended 12/31/66)
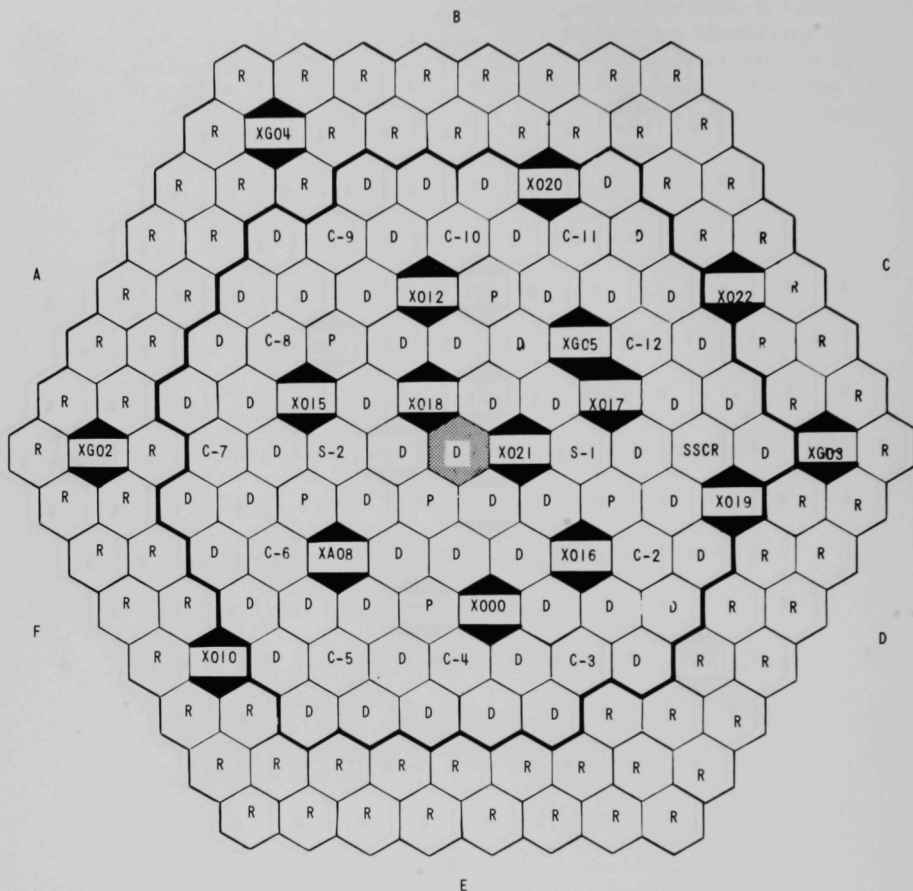
Fig. 2. Core-loading Diagram for EBR-II Run 25, 86-subassembly Core Size* (started 6/29/67, ended 7/20/67)

*Subassembly X011 in position 2F1 during early part of this run.
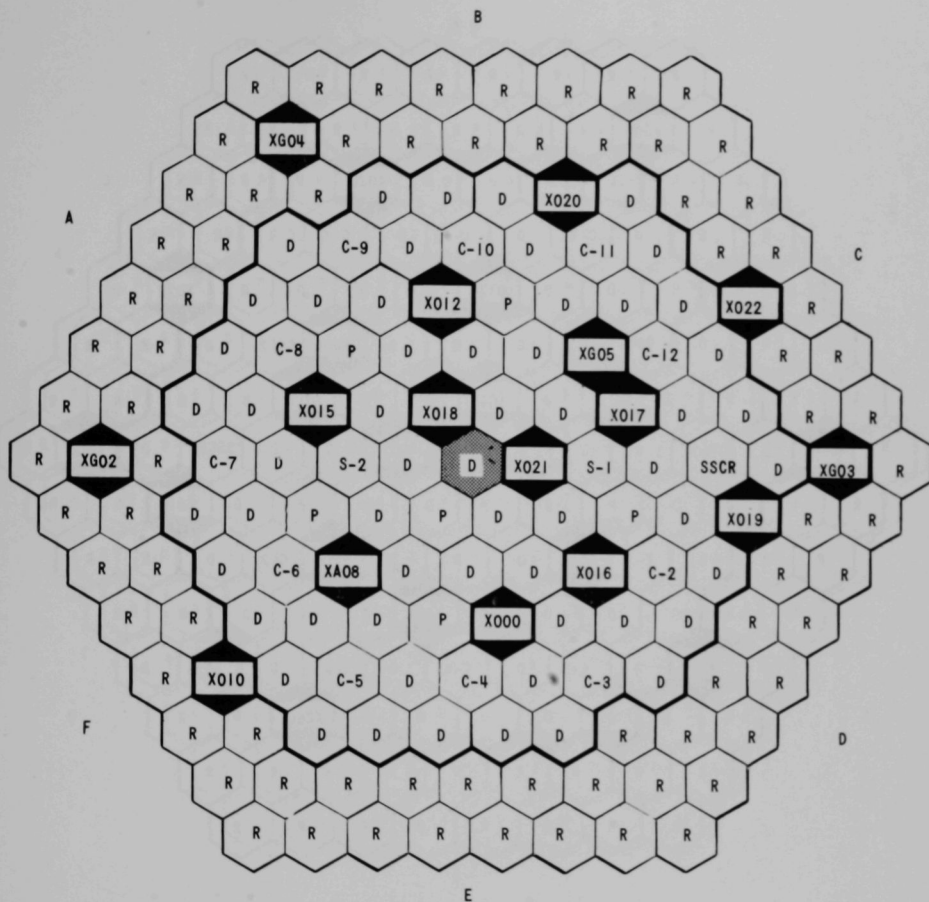
Fig. 3. Core-loading Diagram for EBR-II Run 26A, 88-subassembly Core Size (started 9/22/67, ended 9/24/67)
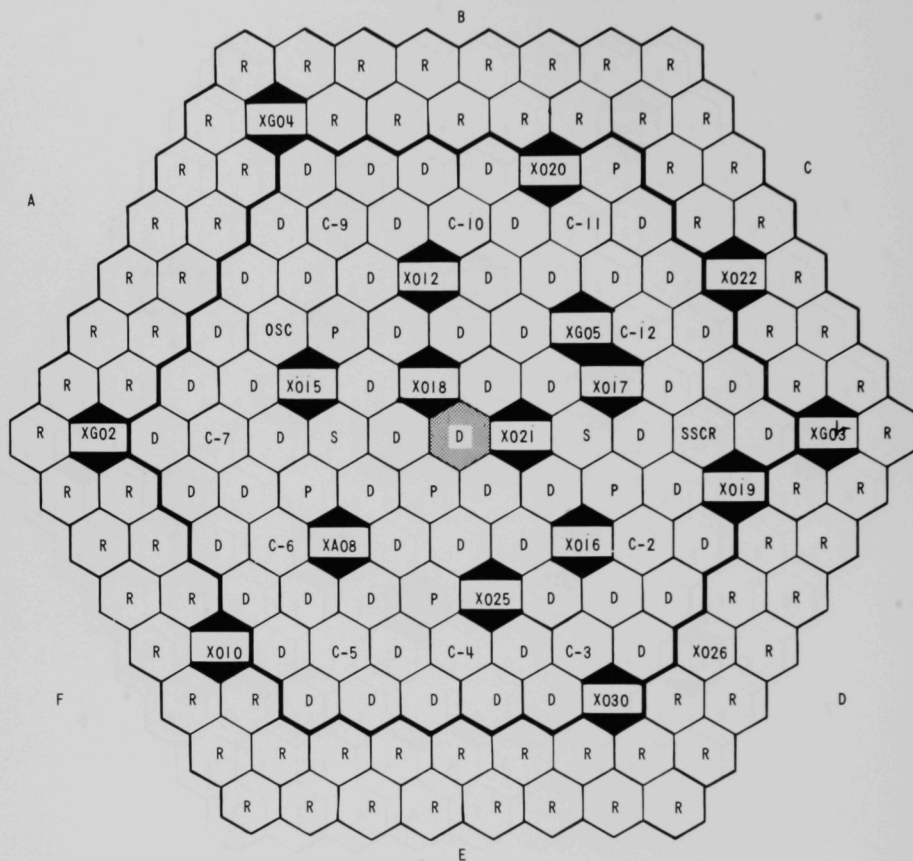
Fig. 4. Core-loading Diagram for EBR-II Run 26B, 91-subassembly Core Size (started 10/11/67, ended 11/20/67)
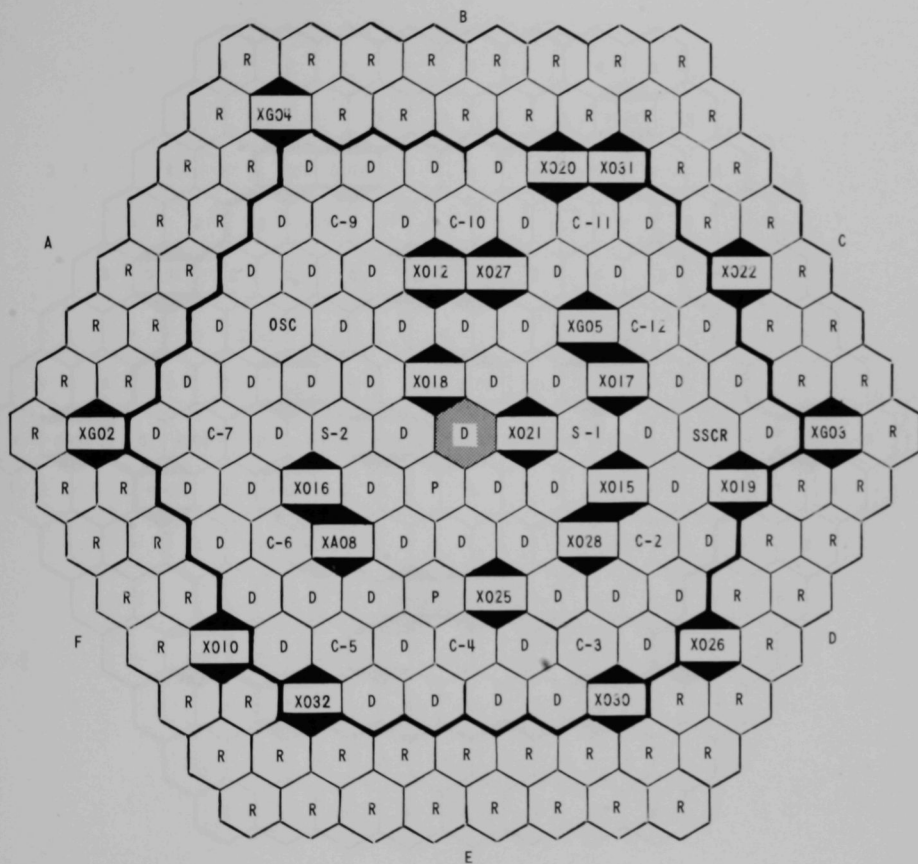
Fig. 5. Core-loading Diagram for EBR-II Run 26C, 91-subassembly Core Size (started 11/22/67, ended 12/12/67)
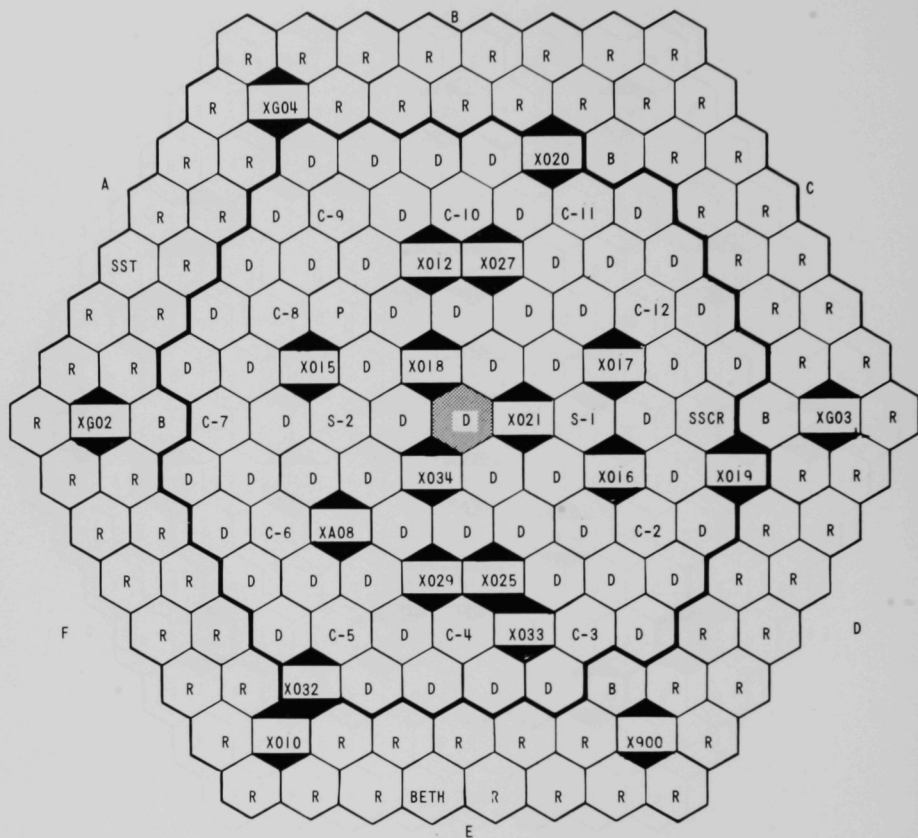
46
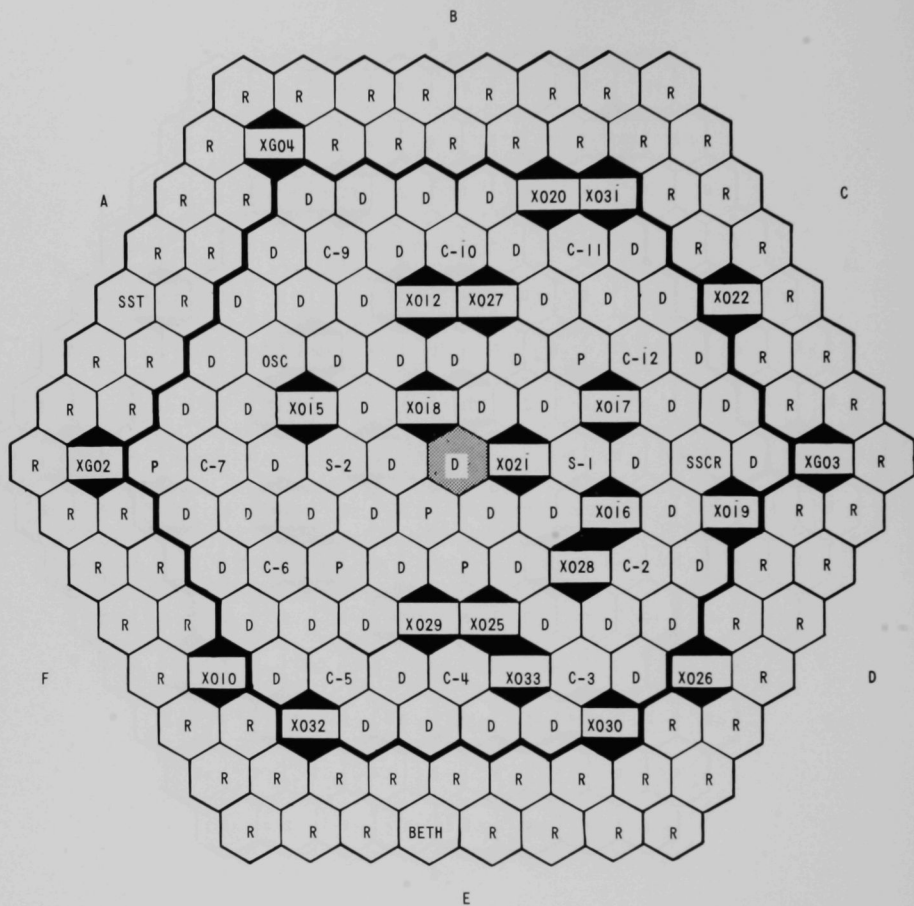
Fig. 6. Core-loading Diagram for EBR-II Run 27A, 91-subassembly Core Size (started 2/2/68, ended 2/29/68)
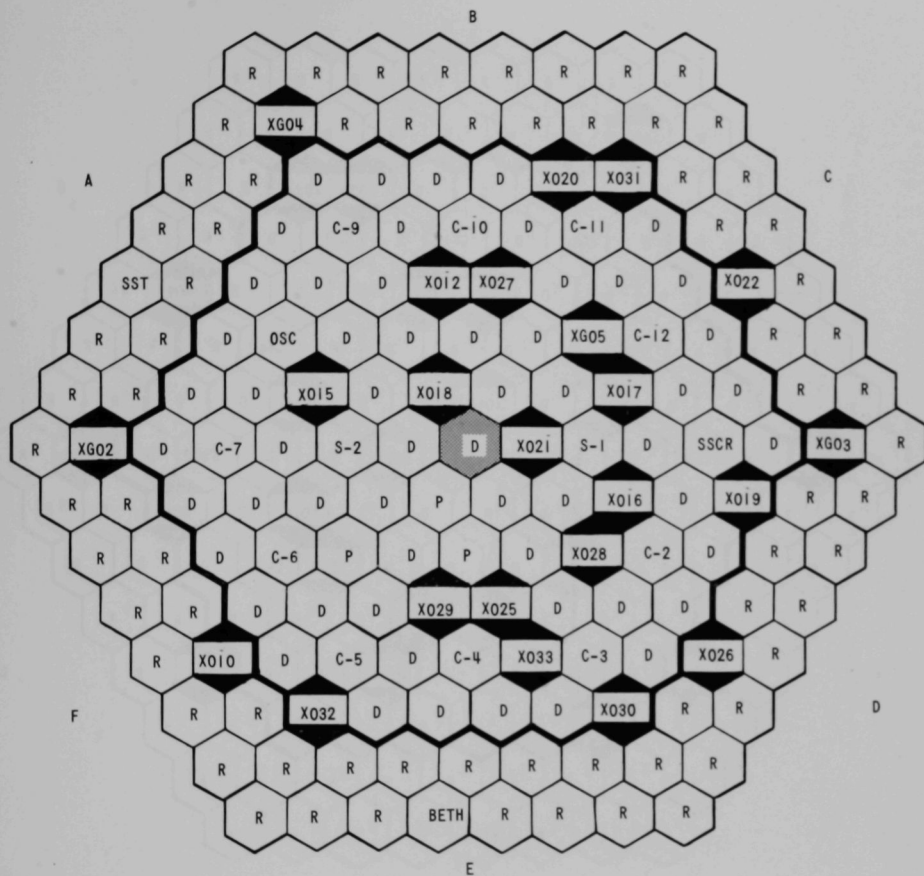
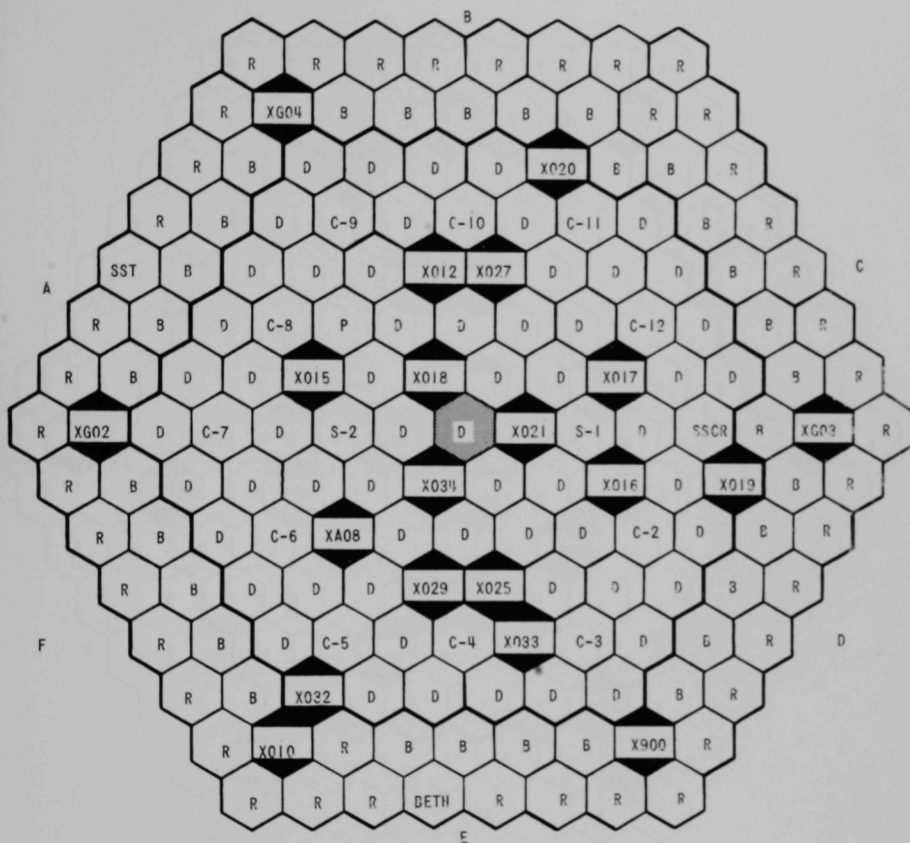Fig. 7. Core-loading Diagram for EBR-II Run 27B, 91-subassembly Core Size (started 3/1/68, ended 3/5/68)

48
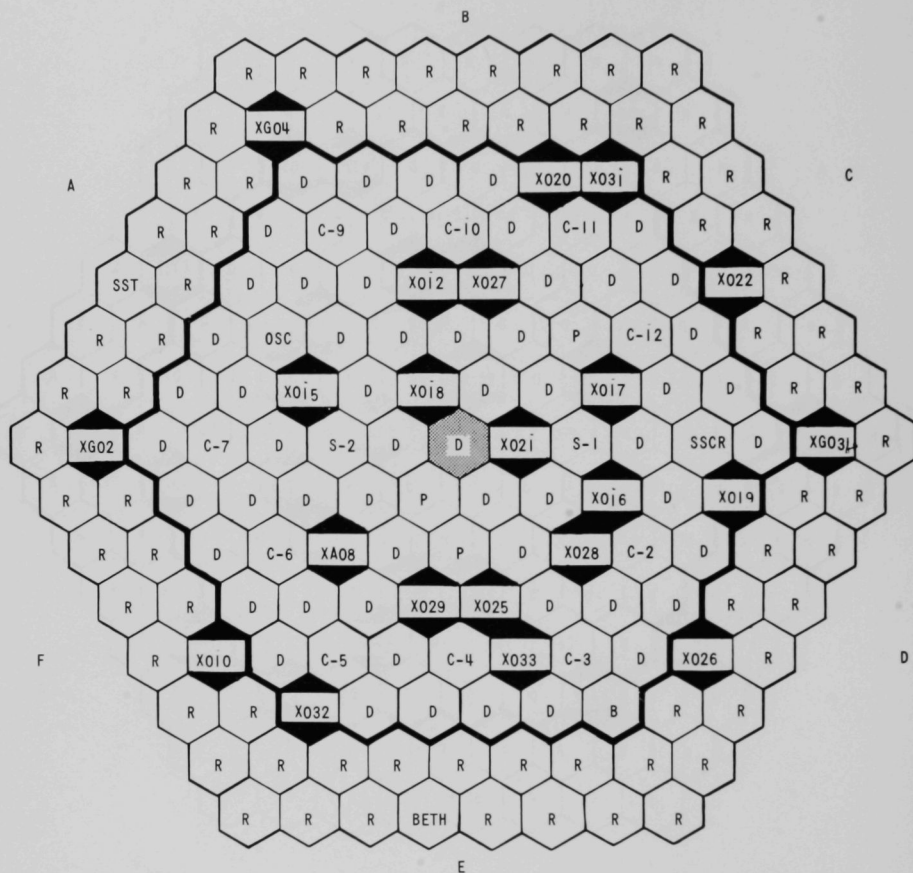
Fig. 8. Core-loading Diagram for EBR-II Run 27C, 90-subassembly Core Size (started 3/7/68, ended 3/11/68)
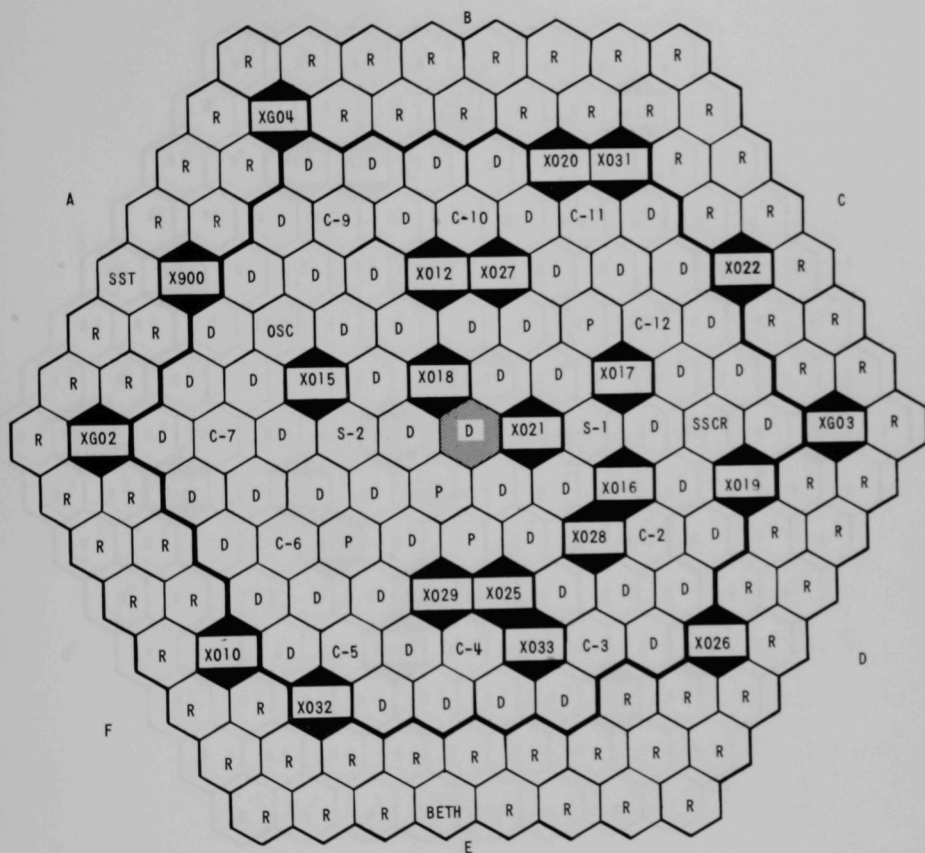
Fig. 9. Core-loading Diagram for EBR-II Run 27D, 90-subassembly Core Size (started 3/30/68, ended 4/6/68)
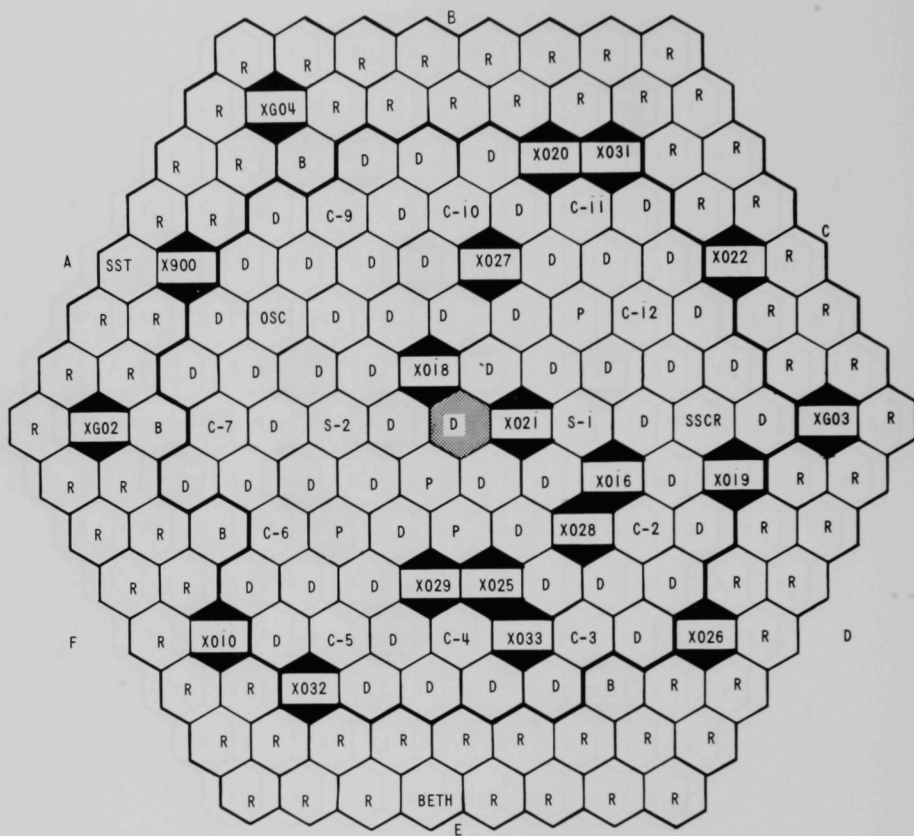
Fig. 10. Core-loading Diagram for EBR-II Run 27E, 87-subassembly Core Size (started 4/7/68, ended 4/11/68)
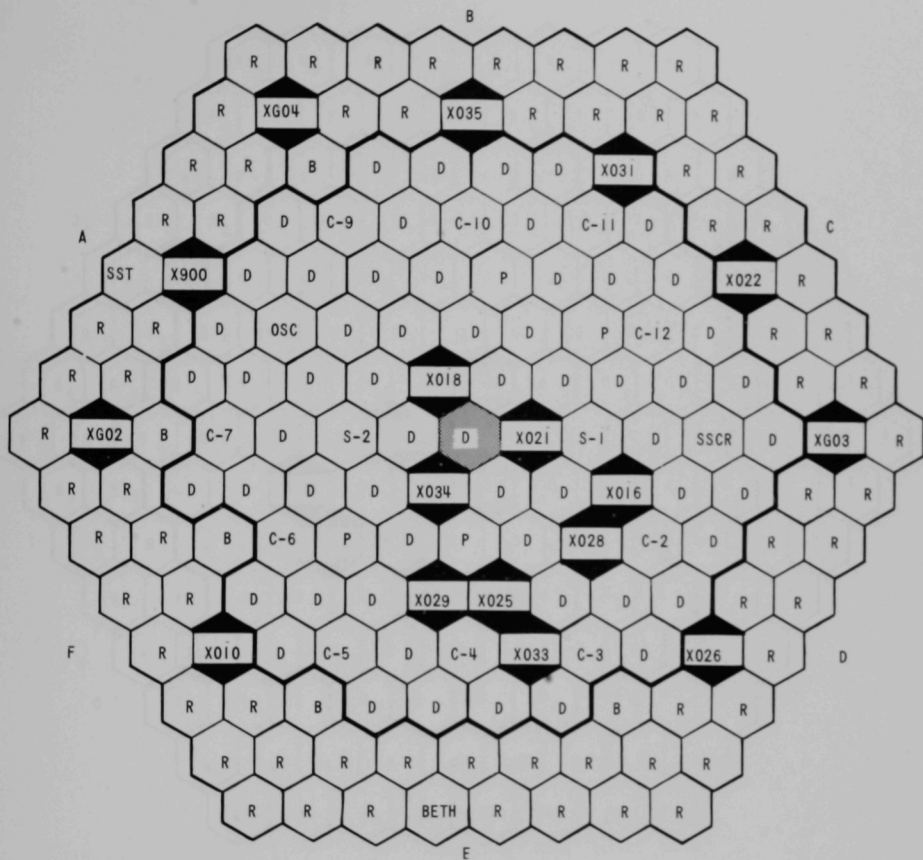
Fig. 11. Core-loading Diagram for EBR-II Run 27F, 86-subassembly Core Size (started 4/13/68, ended 4/16/68)
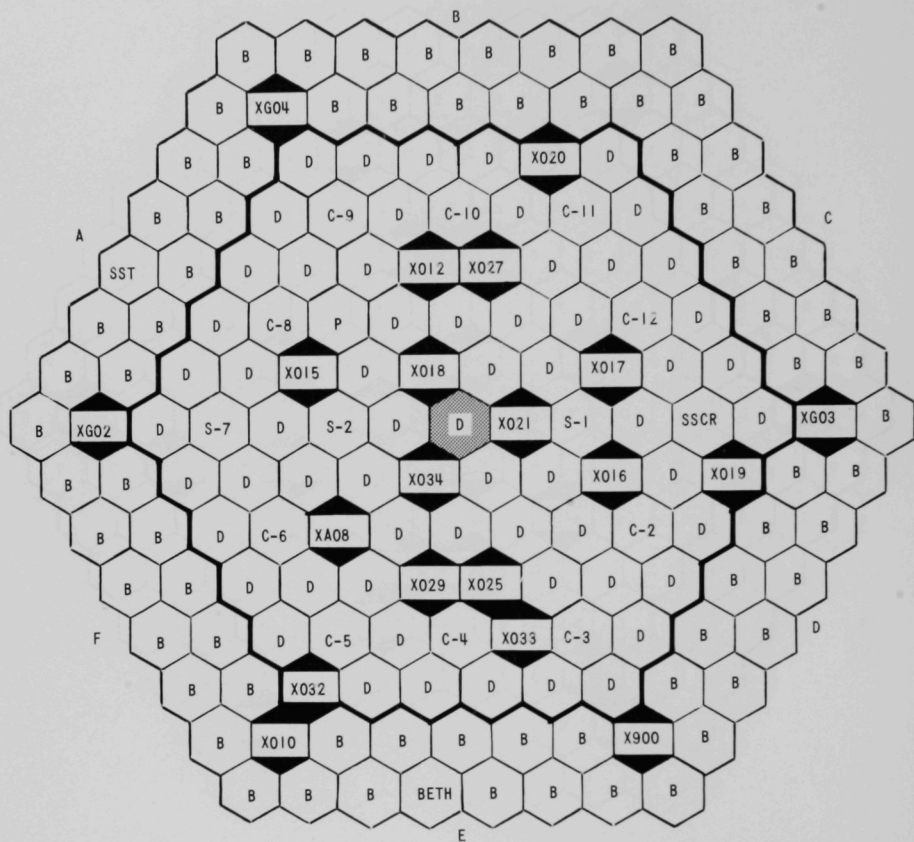
Fig. 12. Core-loading Diagram for EBR-II Run 27G, 86-subassembly Core Size (started 4/17/68, ended 4/19/68)

Fig. 13. Core-loading Diagram for EBR-II Run 27H, 83-subassembly Core Size (started 4/25/68, ended 5/2/68)

54

Fig. 14. Core-loading Diagram for EBR-II Run 27I, 85-subassembly Core Size (started 5/3/68, ended 5/6/68)

Fig. 15. Core-loading Diagram for EBR-II Run 28A, 86-subassembly Core Size (started 5/9/68, ended 5/13/68)
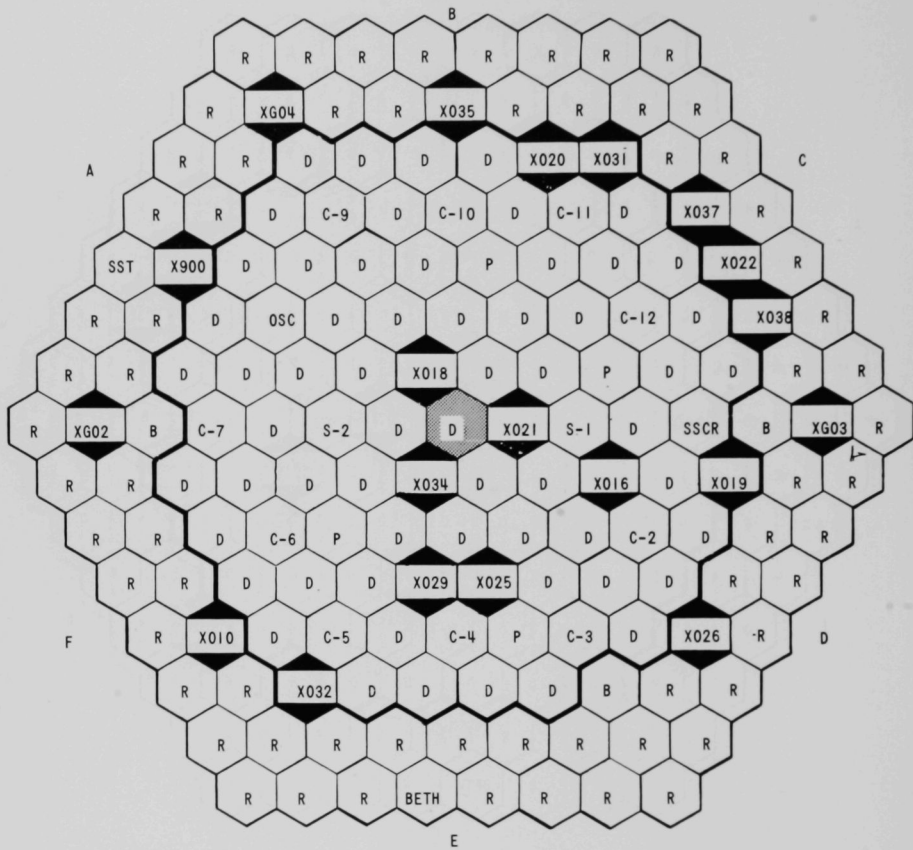
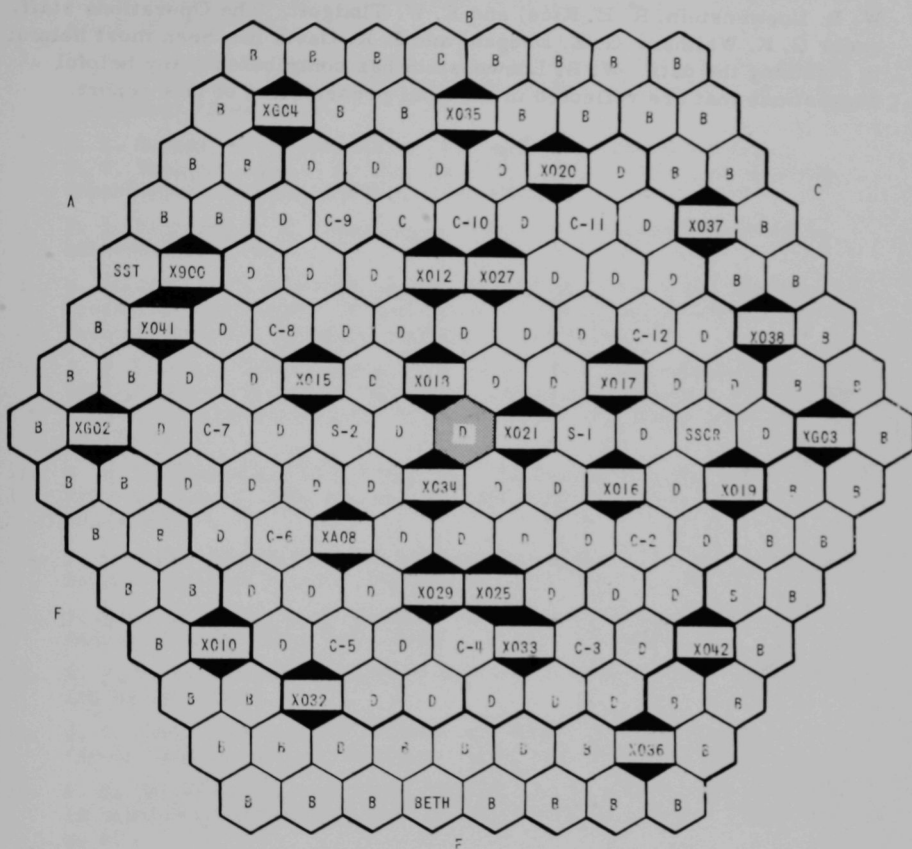Fig. 16. Core-loading Diagram for EBR-II Run 28B, 88-subassembly Core Size (started 5/15/68, ended 5/27/68)

Fig. 17. Core-loading Diagram for EBR-II Run 28C, 88-subassembly Core Size (started 5/29/68, ended 6/15/68)

58

Fig. 18. Core-loading Diagram for EBR-II Run 29A, 87-subassembly Core Size (started 6/26/68, ended 7/5/68)

Fig. 19. Core-loading Diagram for EBR-II Run 29B, 89-subassembly Core Size (started 7/9/68, ended 7/11/68)

Fig. 20. Core-loading Diagram for EBR-II Run 29C, 91-subassembly Core Size (started 7/15/68, ended 7/22/68)

Fig. 21. Core-loading Diagram for EBR-II Run 29D, 91-subassembly Core Size (started 7/25/68, ended 8/16/68)

ACKNOWLEDGMENTS

REFERENCES

1. L. J. Koch, H. O. Monson, D. Okrent, M. Levenson, W. R. Simmons,
    J. R. Humphreys, J. Haugsnes, V. Z. Jankus, and W. B. Loewenstein,
    Hazard Summary Report: Experimental Breeder Reactor II (EBR-II),
    ANL-5719 (May 1957).

2. L. J. Koch, W. B. Loewenstein, and H. O. Monson, *Addendum to Hazard
    Summary Report: Experimental Breeder Reactor II (EBR-II)*, ANL-5719
    (Addendum) (June 1962).

3. R. L. McVean, G. S. Brunson, B. C. Cerutti, W. B. Loewenstein,
    F. W. Thalgott, and G. K. Whitham, *EBR-II Dry Critical Experiments:
    Experimental Results*, ANL-6462 (Feb 1962).

4. F. S. Kirn and W. B. Loewenstein, *EBR-II Wet Critical Experiments*,
    ANL-6864 (Oct 1964).

5. M. Novick, F. D. McGinnis, and G. K. Whitham, "EBR-I and EBR-II
    Operating Experience," in *Fast Reactor Technology*, National Topical
    Meeting, ANS-100, Detroit, Michigan (April 1965).

6. J. F. Koenig, "EBR-II System Heat Balance and Thermocouple Test at
    580°F," and W. R. Wallin "EBR-II Heat-balance Measurements at 50 MWt,"
    Reactor Development Program Progress Report: April-May 1969, ANL-7577,
    pp. 55-58.

7. W. B. Loewenstein, "EBR-II Physics," in *Reactor Physics Division Annual
    Report: July 1, 1963 to June 30, 1964*, ANL-7010, pp. 141-147
    (Jan 1965).

8. J. K. Long, "Correction for Rod-bank Expansion," in *Reactor Development
    Program Progress Report: August 1969*, ANL-7606, pp. 58-59.

9. J. K. Long, *Analysis of the Static Power Coefficient of EBR-II with
    Reduced Coolant Flow*, Nucl. Appl. *6*(2) 116 (Feb 1969).

10. A. F. V. Seixas, *Correlation of EBR-II Instrument Signals*, ANL/EBR-011
    (to be published).

11. J. C. Case, *Core-loading Diagrams for EBR-II Runs 4 through 38
    (April 1965 through mid-December 1969)*, ANL/EBR-007 (Dec 1969).

12. B. C. Cerutti, "Reactor System Testing, Surveillance, and Evaluation,"
    in *Reactor Development Program Progress Report: January 1968*, ANL-7419,
    p. 49.

13. *Reactor Development Program Progress Report: October 1968*, ANL-7513,
    p. 47.

14. P. J. Persiani, "Nuclear Analysis Methods Development," in *Reactor
    Development Program Progress Report: April 1968*, ANL-7445, p. 64.